AT MEN OF SCIENCE

# GREAT MEN OF SCIENCE

## Their Lives and Discoveries

*By*

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# Contents

## *Foreword*

ONCE upon a time a strange and hairy creature gouged out a log and launched it upon a primeval lake. The monster ships that today fret the oceans trace their descent in a straight, unbroken line from that first crude canoe.

Thousands of years ago an inspired genius fashioned a clumsy wheel out of the trunk of a fallen tree—and every wheel, big and little, that turns in the world sprang directly from that ugly, remote ancestor.

The Old Man of the Tribe who held up his ten fingers to indicate the number of enemies he had murdered, suggested a system that now makes it possible to express in numbers the size of distant stars or the speed at which light travels.

What of the savage who first drew on a bit of bark a strange picture, in an effort to warn a friend or frighten a foe? Did not the alphabet evolve from that barbaric design? And did it not, therefore, make possible all the books, magazines, newspapers and circulars that threaten to bury the earth under an avalanche of paper?

Thus in the bitter fight for existence originated the thing we call science. If all the details could be gathered up, all the gaps filled in, the trail of science would be found leading back to half-human creatures who, in terror and confusion, were seeking to be men. Those details are lost, those gaps can never be filled, and all memory of the origin of fire, of clay modeling, of the bow and arrow, has vanished forever.

The story of science, then, is without a beginning and without an end, but it is forever unfolding. Nations rise and fall, dynasties rule and pass away, religions wax and wane, but science, building upon failure and inhumanity and aspiration, moves steadily forward. Its rate of advance is uneven, but for twenty-five centuries it has not come to a dead stop.

Man has made his science, and in turn science has made man. He is thus, in the midst of this thing he calls civilization, literally the product of what he has thought in his head and done with his hands. To know his science, to know the lives of the men who have made his science, is to know Man. To follow the thin, irregular line of searchers after strange truths that leads from antiquity to Einstein, is to find and to understand the finest and most inspiring side of a human nature that is not always exalted, not always kind, not always unselfish.

A golden thread has run through the history of the world, consecutive and continuous, the work of the best men in successive ages. From point to point it still runs, and when near you feel it as the clear and bright and searchingly irresistible light which Truth throws forth when great minds conceive it.

—Walter Moxon, *Pilocereus Senilis and Other Papers*

*Chapter One*

# THALES

WHEN the light of history begins to shine across the plains of Attica, there stands Thales. He was born about the middle of the seventh century before Christ, say 640, and everyone agrees that he lived to be somewhere between ninety and one hundred and ten years old. What he looked like, what kind of every-day life he lived, there is now no way of knowing. Even his nationality is uncertain. Herodotus calls him a Phœnician, but Zeller thinks he was a Greek of Asia Minor extraction.

Examyus was his father, and Cleobuline was his mother. These names are immortal through the accident of parentage. It is assumed that they belonged to the nobility and were wealthy. If so Thales had an excellent heritage—and he justified it.

Some think he was a trader and that it was business that drew him to Egypt. But who were his teachers before he made that excursion into a foreign country? If Examyus was a noble he must have been educated and naturally he would give his son the benefit of his learning. Anyway it is certain that Thales sat at the feet of Egyptian wisdom.

But he was an original. He could accept no man's word as final. He had to know things for himself. The answers furnished by religion were not satisfactory. As he could not live in a world bristling with question-marks, he set out to lay a foundation for his universe.

In laying this foundation he won for himself the title of Father of Science.

2

A few years ago a total eclipse of the sun was visible in some parts of the United States. This is a striking, awe-inspiring phenomenon. After once seeing it, it's easy to understand the terror with which primitive people view it. The sun, they think, is being destroyed, and in order to prevent the calamity they fire innumerable arrows into the air to slay the monster that has attacked the sun. Or they kindle enormous fires to restore the strength of the fainting luminary. They try thus to head off nature by recourse to magic.

Thales, who as a pioneer was scoffed at and ridiculed, wanted to convince the doubters. He knew what caused an eclipse and he computed the time of the next one. In the year 585, he said that the sun would be darkened on the twenty-eighth of May. No one believed him, and the public gave him sneers for his pains. Least of all did the Medes and the Lydians believe him. So on May twenty-eighth, they staged one of their best battles.

But, at the time specified, the sun disappeared, the warring factions were frightened into peace—and the skeptics were convinced.

In spite of his success with the eclipse, astronomy was not his forte. Still he did some things in this field that were worth while. He didn't believe that the sun was a small thing about a foot in diameter—a common belief in his time. He set out to measure it, and his computation showed that it was enormous—one 720th part of the zodiac in diameter. This is considerably less than the true diameter, 864,000 miles, but it gave a much larger sun than anyone before Thales had dared imagine.

He also called the sailors' attention to the Lesser Bear as a better guide by which to steer than the Great Bear, which for centuries had been popular. Careful observation gave him the length of the year as 365 days —fair accuracy when you remember he had no instruments with which to work.

3

In Egypt Thales learned geometry—and proceeded to surpass his teachers. They knew geometry of surfaces —a science they used in keeping track of real estate in a region where each year an overflowing river wiped out all landmarks. Thales passed from these concrete problems to abstractions, and created for the first time in the history of the world the science of geometry of lines. To the high-school student of today his discoveries will seem simple but to the Greeks, twenty-five hundred years ago, they were stupendous. It was he who first stated:

"A circle is bisected by its diameter.

"Angles at the base of an isosceles triangle are equal.

"When two straight lines cut each other, the vertically opposite angles are equal.

"The angle in a semicircle is a right angle."

Each of these is practically self-evident, isn't it? Yet it was out of theorems of this nature that our elaborate geometry grew. And it took a wise man to formulate these when he had to dig them out of his head, without precedent and without rules. The Egyptians had been dealing with this science for centuries, but they never produced, in all their history, so abstract and basic a theorem as any one of these.

But Thales had a practical side to his nature, and he wasn't above instructing the Egyptians in their own field. The priests of the Nile Valley had never been

able to figure out a way of measuring the height of their own pyramids.

"Measure the length of the pyramid's shadow," said Thales, "when your own shadow exactly equals your height." Simple, wasn't it? But the process of reasoning, before Thales arrived at this conclusion, was highly involved, and no one before him had made just the right association of ideas.

4

Great as he was, this first of the scientists dropped into quaint absurdities. He was foolish enough to think his eyes told him the truth. The reasonably wise modern man knew, even before Einstein and Relativity appeared, that sight cannot be trusted. Thales didn't know this. As a result he thought the world was a tiny, somewhat saucer-shaped affair, around which the sun and the moon and the stars revolved. Small and circumscribed as it was, he made his bit of earth occupy the center of the majestic universe.

He was led into another foolishness in his effort to answer the "How?" of creation. To satisfy himself on this point he made water the principle, or primary element, of all things. The importance of water had been forced upon his attention in Egypt where life depended directly upon the annual rise of the Nile. Indeed, Thales lived in a water-bound world. Is it surprising, then, that he should have reasoned that life came out of water and was dependent upon it?

5

With his hypothesis about water as the primary element, Thales started something.

Anaximander, a contemporary of Thales, had ideas that were rather vague, but he was a philosopher who

thought obscurity was a proof of genius. As his primary element he chose chaos, that is, a mixture of air, water, fire, and earth. An internal energy caused a separation in this "Infinite," and hence arose the elements and everything that the world contains.

This old scientist's idea of the earth has never been matched for originality. He taught that the earth is cylindrical, with a base one-third its altitude, and that it is held in the center of the universe by the equal pressure of the air upon all sides. Around his cylindrical, motionless earth revolved the stars and planets, each fixed to a crystalline ring. Beyond them was the moon, and beyond the moon was the sun, all conscientiously moving around the earth.

Life, said Anaximander, came out of the primary miry earth upon which the sun's heat raised blisters, and when these blisters broke, animals appeared as chickens come from eggs. At first these animals were ill-formed, but in time they developed towards perfection.

Man was ejected from such a blister as a fish and as a fish he lived until he was capable of supporting himself on land. How he learned to walk by swimming, Anaximander does not say. This is the theory that has been called the first groping towards evolution. But it's a far cry from blisters in the mud to Darwin's "Origin of Species."

6

Anaximenes, who came a century after Thales, chose air as the primary source of all things. "The earth," he said, "floats like a broad leaf on the air." To him the soul of man was composed of air, since life consists in inhaling and exhaling air and stops when we stop breathing. Warmth and cold resulted from a rare

or condensed state of the air. He even went so far as to call the air infinite and therefore God.

7

Heraclitus of Ephesus was known as the "Obscure Philosopher." This was because he jumbled ethics, theology, physics, and politics in one mess and left his reader to sort it out if he could. Heraclitus made fire the primary element, though by fire he did not mean flame. He meant something more nearly synonymous with our word heat. Still he says, "All is convertible into fire, and fire into all." This principle is in a state of perpetual activity, making and unmaking everything in life.

"No one," he says, "has ever been twice on the same stream, for different waters are constantly flowing down." Which probably is no more than the truth. But he finds that "all is ordered by reason and intelligence, though all is subject to Fate."

He made one contribution to thought upon which later philosophers and scientists have greatly elaborated: "Man's mind can produce no certain knowledge from its own interior resources."

These various schools, celebrated enough in their time, have for centuries been little more than curiosities. They are mentioned as incidents in man's fight away from the Many toward the One. But none of these theories could stand since none of them embodies a truth. Still they served as rounds in the ladder that twenty-five centuries later led to the illuminating theory of the electron.

*Chapter Two*

## PYTHAGORAS AND ANAXAGORAS

ONE name among the ancient Greeks still sings—Pythagoras. In one way or another that name is familiar to almost everyone. If you are inclined to believe in astrology, your favorite seer will din "Pythagoras" into your ears. If you like to probe the future with numerology, you will be told that Pythagoras invented that fortune-telling science. He didn't, but that doesn't matter. In school you heard of him as the man who found out that in a right-angle triangle the square on the hypotenuse is equal to the sum of the squares on the other two sides. You didn't thank him for that and you've probably forgotten what it means. But you haven't forgotten Pythagoras's name.

He was born in 582 B.C. at Samos. Pythagoras made himself immortal by his personality. He had genius, too. But first of all he had the power of winning and holding friends. He was a great talker—and let it go at that. The drudgery of writing was not for him.

His father, the rich Greek Mnesarchus, wanted his son to be educated; so he got hold of the great men of that time, Pherecydes and Hermodamas, and made them teach the youngster. He learned quickly and in less than no time he was beating his teachers at mathematics and philosophy. No use wasting any more time with them.

When only a boy, certainly under twenty, he set out

to see all the wonders of the world from the high places.

2

Picture him then, ready for his journey: a fine laughing boy; tall and straight; an eager face, lighted from within by his hopes, ideals, and burning curiosity. Without worry and without fear, he set out for the East. He carried with him a fat purse—and the dreams of youth.

He went first to Babylon and sat long at the feet of wise men—men who belonged to a race that was old in culture when the Greeks were still savages. There he learned much, but the peace he sought was not in their wisdom. The East still beckoned.

So he penetrated India. The lore of centuries was spread before him. He found much in science, in philosophy, and he also found that which molded all the rest of his life—he found Buddha.

It is not true that Pythagoras was ever an avowed Buddhist. But his mysticism, his stress of the spiritual quality, his impractical dreaming—all showed the influence of Buddha.

At last his feet turned back westward, and he wandered into Egypt. It may well be that it was from the priests of the Nile country that he learned his geometry. Legend says it was there that he first solved his famous right-angle triangle theorem.

3

Back in Greece at last! And what had become of the laughing boy who had set out on travels? He who returned was a quiet, serious man, fifty-three years old. Had he died during those thirty-odd years in the East, the world would never have known his name.

But he lived and came home to talk, to form a brotherhood, to become immortal.

This brotherhood idea he probably picked up in the East where the Buddhists had organizations similar to the later monastic orders in Europe. Pythagoras introduced rites of abstinence and purity and meditation. These were meant, as a retreat is among the Catholics, to cleanse the soul and provide an escape from the "wheel of Birth"—that is, the Fate that tosses one into life and keeps on tossing one.

## 4

Pythagoras got mixed up in politics in the Italian town of Crotona, where he was making his home. And no good came of it. Most likely he wanted to establish a perfect state, but with all his wisdom, he should have known that was impossible. His friends gained a brief victory, but when the hard-headed business men joined hands, Pythagoras and his idealists were turned out.

The sage, with what was left of the brotherhood, went to Metapontum and settled down to a quiet life. There he taught his disciples and passed on by word of mouth the strange mystic philosophy he had loved.

What did Pythagoras teach that could be of interest to a twentieth-century scientist? First he was an astronomer, and his system was the best the world ever heard until Copernicus came along.

He said the world was round and hung in space, and did not stand still but revolved around a central fire, called Hestia. This fire was not the sun, for the sun was illuminated by reflection from Hestia. It was a big thing for any man at that time to say the world wasn't flat and didn't stand still. The planets, of course, were also swinging around this central fire. And in their movement through space they gave off high clear

notes—which we don't hear only because we are so accustomed to them.

5

Pythagoras was mad over numbers—as the numerologists will tell you. But they don't know, and no one else knows, what he really taught about numbers. He had been dead and buried for over a century before any account of his number system was written down. Philolaus of Thebes was the first who tried to tell people what it was about. He knew it only by hearsay, and his report couldn't be accurate and was far from clear. At any rate Pythagoras is said to have declared, "All things are numbers." This might be stretched to fit the modern electron theory—if you add movement, but Pythagoras knew nothing of electrons, and that certainly isn't what he meant.

"He thought the elements of numbers to be the elements of all things," wrote Aristotle, long afterwards. Sweeping along this line he is said to have believed that the universe is simply a musical scale and a number. To "one" he gave the very essence of numbers and made it the basis of all others. So, logically, he could teach, "All comes from one. God embraces all and actuates all and yet is but one."

6

His number theory had one good result. It led him to experiment with musical notes and so discover that vibrating cords omit tones dependent on their length. Out of this grew his statement of harmonic intervals. The instrument he made to test and prove this theory is believed to have been the first bit of physical-science apparatus ever made in the world.

He showed how arithmetic should be joined to

geometry and thus created a new branch of mathematics. He gave, it is said, weights and measures to Greece.

In astronomy, he identified the evening and morning stars, and he was the first to teach that the moon is lighted by reflection.

Of course all of these things were lost but in the fulness of time, when the right man came along, they were unearthed, and Pythagoras helped the world to push ahead.

7

After his retirement to Metapontum, he gave up politics, having had enough of that nonsense. There, surrounded by his friends, who made a fine audience, he was happy. That's enough to make any man happy —if he likes to talk, and you may be sure Pythagoras did.

There is no hint of any dissension among his followers. Probably there were no women there. In fact there is nothing in all Pythagoras's long life to indicate that he ever so much as spoke to a woman. Most of the Greek philosophers had their say about women —and much of what they said wasn't flattering. Pythagoras was silent on this subject. Did he leave his love in Babylon or India or Egypt?

Grown old and wise and trembly in the limbs, Pythagoras died. His death-bed speech is lost; his grave is unknown; even the time of his death is uncertain. It is thought to have been early in the fifth century B.C.

8

Pythagoras the talker was dead; but Pythagoras the teacher lived on. For fifty years his friends carried on

his work. To the man in the street these Pythagoreans were strange people, and therefore to be hated. It was whispered that they did not believe in the gods; that they were infidels and worse. To the wise men the old gods were dying, but to the common people they were fresh in eternal youth.

So the mob could not endure the impiety of men who dared to doubt. The Pythagoreans were in the habit of meeting together at the house of one of their number. There they talked of the Master, rehearsed his theories, planned for the further spread of his ideas.

But to the devout worshipers of Zeus these meetings had a devilish air. They could not be decent. Why tolerate them? Outside of Milo's house, in which the brotherhood was gathered, a mob assembled. Milo and his friends ignored them. The mob pressed forward. It was but the work of a minute to smash down the door. The mob found them, those heretics, Milo and the others, and massacred them, burning the house above the fifty and more mutilated bodies.

So ended the school of Pythagoras. Victims and assassins have for centuries mingled their dust. The gods in whose honor the murders were done have passed from the Olympian heights. They themselves have become dust of myths. But Pythagoras lives, and every student sits at his feet, listening for an overtone from the "music of the spheres."

9

Pythagoras, with his weird theory of numbers and his obscure references to an unknown future, gave place to Anaxagoras and an almost stark reality.

This scientist of Clazomene, born in 500 B.C., came

into the world about the time Pythagoras was leaving it. The son of a rich father, doubtless he was given every chance to develop his natural ability. Where he studied and with whom is unknown, as the first forty years of his life are wrapped in obscurity. Probably he traveled—that was the one sure way of learning, at a time when books were bulky and far from plentiful.

He is first clearly seen when he enters Athens about 460 B.C. The Athens he invaded had only just become the intellectual center of Greece. Pericles, Euripides and Protagoras were the great men of the time and with them Anaxagoras formed friendships. For thirty years he was a powerful influence in the city's intellectual life.

Devoting his time and money to science and philosophy he came at last to feel the pinch of poverty and want. Other troubles, also, crowded upon him. He was out of sympathy with, if not actually opposed to, the popular religion. And that, at any time in the history of man, has been a dangerous position to occupy. The common people will not have their gods slighted. When Anaxagoras said the sun and moon were composed of earth and stone he was blasphemous; when in addition he scorned the miracles, praise of which was in everyone's mouth, he was flirting with death.

After enduring him for thirty years the mob decided it had heard enough of this fellow. He was accordingly arrested, thrown into prison, condemned to die. Pericles, whose power was waning, still had enough influence to save his friend's life but not enough to secure his safety if he remained in Athens. So Anaxagoras went away from there, found a refuge at Lampsacus where he died, full of years but empty of fame and honor.

Afterwards those who had been ready to stone him busied themselves weaving legends around his name.

10

Anaxagoras introduced an Intelligence, a Mind, to start matter whirling. After that the elements took care of themselves. These elements were changeless and indestructible—this idea closely elbows a modern belief. He also foreshadowed the atomic theory with his notion that in the chaos stirred up by Mind were the germs, infinitely small, that were later, by internal affinity, to combine into the substances that make the visible universe.

He came close to anticipating a theory that made Kant and Laplace famous when he said that the sun, moon, and stars had been torn away from the common center of the earth by the violence of the original revolutions.

Like Pythagoras, he said the moon shines by reflected light, and he pointed out that when the moon is eclipsed the earth is between it and the sun. He anticipated Galileo and insisted that there are mountains and valleys on the moon like those on this earth. He taught that there have been great epochs in the history of the earth and that during the ages the globe had been greatly changed by fire and flood. He was bold enough to say that one day the hills of Lampsacus would be under the sea—if only there were time enough.

In biology he used his eyes to some purpose, and found out that fish breathe through their gills—a fact that no one before him had noticed. He said that plants were living creatures and had some form of breathing. He also thought they suffered joy and pain—joy when the buds came out and pain when the leaves fell.

II

He was something of an anatomist and was first to call attention to the lateral ventricles of the brain, which he thought was the first thing developed in the embryo. He taught that the male child is matured on the right side of the mother and the female on the left. Acute diseases he attributed to the movement of gall to the lungs and pleura.

As you see, Anaxagoras's ideas were a jumble of fact and fancy. What he didn't know he guessed at. That was the genius of Greece—it had to have an answer, even though the answer was wrong. Many things, of course, he could not know. He had nothing to help his eye to see the very small or the very distant, and he knew nothing of chemistry. In the main, however, he was moving right, and his name deservedly lingers in the histories of science.

## *Chapter Three*

# DEMOCRITUS

ABDERA, in 460 B.C., was a poky, uninteresting town in Thrace. Its inhabitants had decided there was nothing left in the world to think about, so they stopped thinking and gave their attention exclusively to business. Into the midst of these complacent traders Democritus, sage and scientist, was born. He was born into a home in which the great Xerxes had been entertained. As a gracious exchange of courtesies, the king left behind, to act as teachers for the boy, some of the wise men who were attached to his court. This story may not be true, but it is true that Democritus was taught—and taught well. It is also true that given his genius, nothing on earth could have kept him from learning.

Whoever his teachers were, travel, as usual, was his main instructor. Indeed, he traveled so much that Democritus could say of himself:

"I am the most traveled of all my countrymen. I have extended my field of inquiry farther than anyone else. I have seen more countries and climes and have heard more speeches by wise men."

Probably he was not just boasting when he said this.

He had no interest in property and when his father died he gave the land to his brothers, taking for his share the ready cash. Thus he was fixed to satisfy his craving to see the world. He visited Egypt, Ethiopia,

Persia, and India. He met officials, priests, and laymen and listened to the "speeches of many learned men."

Doubtless his adventures were not all confined to the pursuit of knowledge—but over these human-interest trifles history has drawn a veil. When he returned home time and many changes had chastened him, had drawn his brows together and lowered heavy lids over eyes that had seen too much.

2

Not long after his return the dull traders of Abdera were calling him the "laughing philosopher," a term given in mockery because to those Abderians, Democritus was mad. He had squandered his substance in fruitless travel, and when he settled down he refused to busy himself with a "useful" occupation. Instead, he spent his time laughing at the feeble little folk who wasted their lives gathering goods that could not pass the portals of the grave. He laughed at their ways, at their seriousness, at their blazing egotism, which told them they were worth while in the scheme of the universe.

Democritus did not believe they were worth while—not to the universe. The universe could get along very well without them. They had a right, he felt, to be serious in their human relations. He admitted each one was important to the home, the city, and the state. But to the universe, to that majestic parade of stars and planets, to the swift-winging meteors, to Time and Space, they were no more, individually or collectively, than the motes that danced in the sunbeam.

He laughed at the little ways of men who counted themselves big in the presence of Infinity.

And the people of Abdera, honest worshipers of all the gods, called Democritus mad.

3

His perfectly sane friends sent for Hippocrates, the world's greatest doctor, and submitted to him the proposition that "this Democritus isn't just right." Probably this professional visit was the first meeting of these two men.

Hippocrates came as a physician to minister to a madman; he left as a worshiper hailing a genius.

Of what did they talk, these two? Of medicine? Doubtless, for Democritus knew something of medicine and wrote on it. Of the far East and the places Hippocrates had never visited? Of politics and the fast-growing importance of Athens? Of the patient's supposed madness? Probably not. Hippocrates must have known instantly that here was no need for a physician.

After endless talk the doctor went back to those who had called him to Abdera, and voiced his admiration of their famous townsman, telling them: "If there is insanity here you yourselves are the victims and not Democritus."

In after years, it seems likely that there were other meetings between these two and tradition says they exchanged many letters. Those in existence are not thought to be authentic.

Ninety years old, impoverished, famous, and still laughing at the folly and futility of men, this jolly old philosopher died.

4

Democritus believed in the atom. To him it was an infinitely small, invisible particle that moved about through space. His atom had size, but it was physically indestructible and could not be divided. Of these atoms, which differed in size and form, the sub-

stances of the sensory universe were composed, the heaviest atoms naturally sinking and the lighter rising to form the atmosphere. Some of the atoms he said were smooth and rounded; those that compose the soul being the finest, smoothest, and most active.

He taught that there is nothing in the universe except atoms and the void—by void he meant room for the atoms to move. He regarded the sensations of special senses, as taste and touch, as objectively false. "By use there is sweet, by use there is warmth, by use there is color. But in truth there are only atoms and the void." Again: "By the senses we in truth know nothing. We cannot know reality in this way. For truth is in the depths."

He taught that the brain is the seat of thought, the heart of anger, and the liver of desire. There were great men after his time who did not locate thought in the brain, but considered that organ merely a medium for cooling the blood.

Democritus wrote on diseases and their causes, on prognostics and on diet. He knew of the pulse and called it the "beating of the veins." He had the highly original notion that the unborn infant gets nourishment by sucking the placenta and hence knows what to do when brought to the breast!

Epidemics, he thought, were caused by the bursting of heavenly bodies and the falling to earth of the atoms that composed them. These atoms, being of the heavens, were, naturally, enemies of mankind and brought sickness. This theory might be strained to hint at the modern discovery of microbes.

He is credited with saying: "All men ought to know the art of medicine. The mind grows as long as health is present, which the wise man should take care of. When the body suffers the mind no longer troubles

about the practice of virtue, for disease darkens the soul."

Sleep he said was caused by the escape of a certain number of atoms. When a great many of them escape, a deathlike state ensues. If all of them get away, we die. The atoms do not die, but they cease to function as a human body, and our immortality consists in the indestructibility of the atom.

5

Democritus taught the existence of a multiplicity of elements. Thus he struck at the egotism that made this earth unique. His atoms extended space—they made possible solar system after solar system. To him the geocentric design—that is the earth at the center of the universe—was unnecessary. But vanity is the last thing to die in the human race, and many centuries were to pass before men became sufficiently humble to admit that their earth was a bit of dust whirling through space, held to its course by a central sun.

He pictured a finely formed soul, fitted to the physical body and composed of atoms which he identified as those composing fire. These atoms, he said, permeate the whole body and in specialized organs perform specialized functions.

The moral character, he said, is determined not by a man's acts but by his will. Was he there leaning toward motive as the test of morality? He believed that wisdom lay in trying to attain calm of the body, that is, health, and calm of the soul, that is, cheerfulness. The good of the soul, he thought, was infinitely better than the good of the body. The dominant principle of his mental life is found in the phrase:

"Wealth of thought, not wealth of learning, is the thing to be coveted."

*Chapter Four*

# HIPPOCRATES

MAN'S fight for health has been strangely intermingled with his religion. It is still thus entangled; and prayers for the recovery of the sick are of every-day occurrence. This is natural, for much bodily suffering exists only in the mind, and when that is set right physical health results.

Man's fight for health began in the jungle where accident played a leading rôle in limiting his years on earth. Even in prehistory days science was taking its part in this grim fight. Fossils have been found which prove that men of the Stone Age knew enough to set broken bones and bore a hole in the skull to let out the devil that was torturing the victim.

When history begins, the priests were the doctors, and their gods were directly responsible for cures or fatalities. So religion and faith in the few struck hands with superstition and ignorance in the many and side-tracked the science in which men should have been first of all interested.

2

In Greece Æsculapius was the god of healing. Ruins of temples erected to him still exist. He was a great god and a popular one, for what is more desirable than health and freedom from pain? At his shrine prayed the weak and the suffering and then laid them down to sleep.

In their dreams the god sent miraculous agents to lay hands on them, so that they woke cured—sometimes. Often the god was deaf, and the poor wretches dragged themselves homeward to die.

That the god was kindly and efficacious is proved by the countless testimonials left by those who found health at his shrine. A man whose fingers were paralyzed prayed to Æsculapius. In a dream the god took the victim by the hand, and in the morning he woke cured.

Blind Alcetas dreamed that the god's hands were laid on his eyes. In the morning Alcetas could see. A dog at the temple of Æsculapius licked the blinded eyes of Thyson and they were made well. Arata's daughter was afflicted with dropsy. Arata prayed at the temple at Epidaurus and then dreamed a strange dream. When she returned home she found her daughter had dreamed the same dream—and was cured.

Are these testimonials authentic? Certainly they give Æsculapius a fair reputation as a healer. But don't forget that all of the medical knowledge of that time was in possession of the priests of the temple. Isn't it likely that these learned men occasionally gave a helping hand to the benignant god?

Free-will offerings on the part of cured votaries were the sole means of support for the temple. The priests seldom looked kindly upon a scientific practitioner who threatened their income. The cult of the god had to be maintained, and the efforts of the vulgar doctors were frowned upon.

And then appeared Hippocrates. He didn't care a rap about the priests and probably he wasn't especially interested in Æsculapius. He wanted, before all else, to make men well, and in order to do that he had to find out why they were sick.

3

Hippocrates was born on the Island of Cos about 460 B.C. Legend traces his ancestry through his father to Æsculapius and through his mother to Hercules. If this line of descent is accepted, he certainly proved an ungrateful son, for he dethroned Æsculapius and by so doing threw a shadow over the labors of Hercules.

The physician Heraclides was his real father, and Phænarete was his mother. At first he studied medicine with his father, but went later to sit at the feet of the great doctor, Herodicus of Selymbria. It was this Herodicus who used to make his patients walk twenty miles in an effort to rid them of objectionable "humors."

Then he rounded off his studies by traveling, but his wanderings were much more limited than those of his predecessors. The Far East he did not see, and it is probable that he never got to Egypt. He practiced his profession on the Island of Thasos and in various towns of Thessaly.

His first distinguished patient was Perdiccas II, king of Macedonia. His next was Democritus. While he was in Macedon he decided that Greece was threatened with a plague, and nothing that Perdiccas could say would induce him to remain abroad when his native land was in danger. He went at once to Athens, and by causing large fires to be lighted throughout the town averted the epidemic. He noticed that blacksmiths escaped the plague, and this, it is said, gave him the idea for the purifying flames.

4

Born of a family of physician-priests he broke clearly and finally with that cult. He threw away amulets and

refused to admit the power of prayer. He was a rebel against the camp of Æsculapius. What the priests in the temple thought of all this it is now impossible to say. However, it does not appear that he was persecuted and it is not on record that any attempts were made upon his life. After all he was only one man, and the sick were plentiful.

Only one man! But he shook down the temple of the god and started a reformation that is still sweeping mankind into clearer conceptions of disease and health.

He was fearless and he was honest. There were many, many things he did not know; but one thing he clung to: his desire to know. He was another of those original skeptics who must see with their own eyes and touch with their own hands—and who even then are not quite sure.

His ethics were most exalted, and out of the regard he had for his profession and for men he evolved the "Hippocratic Oath," in taking which the young physician of 1929 swears:

"With purity and holiness I will pass my life and practice my art. . . . Whatever in my professional practice I see or hear in the lives of men which ought not to be spoken abroad, I will not divulge."

At the age of ninety or more Hippocrates died at Larissa in Thessaly. He passed on into the ages, and around his name legend and romance have woven strange tales.

## 5

Hippocrates was the first in medicine to *see* and to reason about what he saw. He threw away legend and vulgar beliefs and tried to dig his way into the secret of health.

He wanted to know, but he wanted to know for the

purpose of curing the sick. He had no desire to dazzle his patients, to deal in the mysterious, to bluff. Of two systems of treatment, he made it a rule to choose the less spectacular and impressive. He said exhibitions of skill done to impress the patient were a form of deceit, and above all he wanted to be honest with those who visited him. He carried this honesty to the point of refusing to treat those whose condition he considered hopeless.

He tore medicine away from philosophy and made it a science. He created a sound method of procedure and made it possible for those who came after him to take up the work where he dropped it. It was not his fault that for many centuries advance practically ended with his great successor, Galen. He had shown the way, and later man returned to start where he stopped.

6

Hippocrates taught that the human body is warmed with a natural, internal heat and the loss of this heat causes death. This heat, he thought, was most prevalent in the baby and throughout life slowly diminished until at death it vanished. This heat he ascribed to the heart—a surprising guess on the part of one who had dissected no human body and who knew nothing of the circulation of the blood.

The bases of his diagnoses were the four humors—blood, phlegm, yellow bile, and black bile. In health these are mingled in the proper proportion—that is, the right "mixture." Just exactly what the right proportions are Hippocrates does not say. But the wrong mixture means sickness and the right means health.

When Hippocrates was called to attend a sick man he at once began his treatment. This, however natural it may seem to us, was a radical break with precedent.

In Egypt and elsewhere it had been usual to let the sufferer lie and do nothing until the fifth day. At the end of that time, if the patient still lived, an effort to relieve him would be made. Under such a system, death probably would save the doctor a lot of trouble. At any rate, Hippocrates saw no sense in this practice and entirely abandoned it.

He watched carefully what his patient ate and was thus the first of dieticians. To eat sensibly was to be healthy and to diet wisely was to regain health. To him the difference between good and bad doctors consisted in how the remedies were administered and with what skill the diet was prescribed.

In his time there was no generally accepted system of treatment for acute diseases. Hippocrates had to pioneer his way. His contemporaries not infrequently let their patients starve to death. Hippocrates denounced this foolish practice. Barley water, sweet wine, and hydromel were employed by him where the patient was too weak to take heavier nourishment. Hydromel made by boiling honey in a large proportion of water would provide considerable food, and yet people who let themselves die of hunger were in the habit of taking only hydromel. If they took enough of it, death from starvation must have been long in coming.

Hippocrates upset all previous notions of treatment in cases of fever. He said that when the system was weakened by fever, great care should be exercised in the matter of food and exercise—all changes at that time being dangerous. In this he approached rather close to modern ideas. Before his time many had been killed by the fever treatment which called for violent exercise and heavy food—a sort of exorcising regimen, suggesting a religious origin.

In general, he seemed to feel that an excess of health

was close kin to sickness. This idea is expressed in the axiom, "The well know not of their health, but the sick only." As a result of this theory, he strongly advised moderation in all things—the golden mean was his conception of a wise life.

7

Though he had inherited from the physician-priests who preceded him 265 drugs, he used them sparingly. In the main he was content to rest on climate, water, and diet and—let nature take its course. He wrote of the influence of winds, waters, and stars, and his analysis of the effects of climate is still considered sound. As to the stars—well, he was not wholly weaned from the dark past that so closely shouldered him, and he thought that at the rising of Sirius and Arcturus and at the setting of the Pleiades disease was more than ordinarily rampant.

He repudiated the ancient notion that disease was sent by the gods as punishment. Even to the "Sacred Disease," epilepsy, he denied divine origin. No disease, he said, is more divine than another. All of them are caused by natural agents, and among these natural agents he enumerates heat and cold, wind and sun.

He knew something of the bones, their relations and positions. Of the muscles and the internal organs his ideas are confused and often wrong. Of nerves he knew nothing; the "nerves" to which he refers are really sinews or tendons.

The brain he thought was a gland which exudes a viscid fluid, and it is by no means certain that he identified thought with activity in the brain. He describes the kidneys as glands, but thought they had an attractive faculty by which the water was drawn from the fluids drunk and then descended to the bladder.

8

As you smile at Hippocrates's blunders don't forget that he had never seen a human body dissected, that he had no microscope and no chemistry. He knew nothing of microbes and nothing of the subtle processes of the glands. He was as one in an unlighted room trying, without tools, to mend a delicate apparatus. His efforts were crude and clumsy—but he did not ruin the machine over which he labored.

On every side of him he toppled over the images of superstition, for he declared disease to be born of natural causes. He plucked away its false mystery and thereby robbed it of much of its terror. He found medicine dying in the temples of a worn-out religion. He left it dominant and vital, set upon its high mission of relieving pain.

*Chapter Five*

# ARISTOTLE

ARISTOTLE, the Stagirite, was the first of the students of nature and among the last to combine science and metaphysics.

During his lifetime Philip subdued Athens, Alexander conquered the world—and the glory that was Greece forever passed away. Henceforth Rome overshadowed Europe, and the scene of history moved westward to the peninsula of Italy.

Aristotle was born at Stagira on the Strymonic Gulf in 384 B.C. His father, Nicomachus, traced his descent to Machaon, who was said to be a son of Æsculapius. One can throw out this divine ancestry and still account for Aristotle's natural bent towards science. His father was physician and friend to Amyntas, king of Macedon and grandfather of the world-conqueror whom Aristotle was destined to teach.

Probably his father was the scientist's first teacher. At any rate it seems certain that he learned something of medicine and became a member of the Asclepiads—a medical fraternity. When did he get time to study his profession? Historians give him a wild youth, and even those who send him to Athens at eighteen do not picture his boyhood as above reproach. Some say he squandered his money in riotous living, joined the army to ward off starvation, and after many wanderings returned to Stagira to recoup his fortunes with the practice of medicine.

But all agree that he studied with Plato, whether

eight or twenty years is uncertain; that he was a shining pupil and referred to by the great philosopher as "the intelligence of the school." This delightful harmony between the two geniuses did not last. "Plato is dear but truth is dearer," said Aristotle. Plato wrote, "He has spurned me as colts spurn their mothers." Unfortunately for Plato, but fortunately for the world, Aristotle was a man who would disagree with divinity itself until divinity convinced his intelligence.

2

During his residence in Athens, Aristotle attracted the attention of Hermias, king of the city-state of Atarneus, and was invited to that ruler's court. The result of the visit was a wife, Pythias, daughter or niece of Hermias. By this princess wife he had one daughter, Pythias; and by Herpyllis, his common-law wife, after the death of Pythias, he had a son, Nicomachus.

Upon the death of Plato in May, 347, Aristotle went to stay with Hermias with whom he remained for three years. Afterwards he went to Mitylene for a year. While there he was summoned by Philip of Macedon to take charge of the thirteen-year-old Alexander, for whom the king entertained the most exalted plans.

Here rises a question that has been asked over and over for two thousand years: What did Aristotle teach the future tyrant and conqueror of the world? What was there in the after life of the ruler to show that he had come under the influence of one of time's great men? Did Aristotle feed that uncontrollable ambition? Did he give to Alexander the training that made it possible for him to think himself of divine origin? Where were the temperance, the control, the self-discipline, the humility in the presence of the Unknown, that one would expect a philosopher to inculcate?

Doubtless the truth is that no one could teach Alexander. He was an original, probably with a diseased mind. His chief delight was to tame horses that no other man could tame. That is the keynote of his nature. To such a boy no philosophy would appeal and only the science of war would interest him.

3

For seven years Aristotle was in Macedon. When the murder of Philip called Alexander to the throne, the teacher returned to Athens. He was fifty years old, and had he died then his name hardly would have lived in history. The great bulk of his immortal writing was still to be done. Fifty! And Aristotle had lived hard. In the statue in the Palazzo Spada at Rome, the face is etched, but the arm is sinewy and powerful; the mouth is touched with bitterness, and illusion no longer animates him. He has looked deeply into the hearts of men, and as a result his writings about the soul and immortality will be vague and tinged with skepticism. What did he expect that has not come to him and now, at fifty, will never come? Hope and ideals and trust that have gone have drawn lines on his face, and something of pain and something of a divine despair are on his lips and in his eyes.

4

In Athens Aristotle set up a school for himself and became the head of the Peripatetics—walking philosophers. His lectures in this Lyceum, reduced to writing, probably constitute the bulk of his books. Unlike his predecessors he did not confine his work to metaphysics, but he had to start with this uncertain subject, and his hardest job was to get away from it. Every manifestation of life was alive with interest for him. He took the

whole province of science for his subject and he proposed to write the last word on each branch from his own observations and reflections.

Striking a new line he threw away hypotheses and looked before he talked. Thus he gave to the world its first great lesson in inductive thinking. He made mistakes, but his mistakes were transitory; he blazed a trail in the search for truth.

During the twelve years that he lived and taught in his school he was a busy man. The world was his garden and from the ends of the known earth he brought strange animals to furnish him with data for his natural history; he collected books all his life with such avidity that Plato referred to his residence as "the house of the reader." He studied plants and climate and astronomy—and he wrote. He must have written at top speed if he was the author of the thousand volumes credited to him by the ancients.

All of this work was carried on in the midst of an alien people. Not for a moment did Athens accept Aristotle. To them he belonged to the camp of the Macedonian tyrant, and they hated Alexander. During this time Demosthenes was denouncing Alexander and railing against the party in Athens that supported the tyrant. And in this party, head and shoulders above them all, stood Aristotle. It was impossible for him to contend that he was a philosopher and indifferent to politics. Was not Alexander his pupil—his product?

There were no quiet days for this first of inductive scientists. The peace and veneration that were Plato's were denied to him. He worked at fever-heat in an atmosphere that was electric. Probably, during all of those years, there was not one minute when the Athenian mob would not, gladly, have torn him to pieces.

After his break with Alexander his condition was

not improved and it may even have been worse. Callisthenes, nephew to Aristotle, was the cause of this break. For some reason known only to himself Callisthenes refused to treat Alexander as a god. The conqueror, while in Egypt, had got the notion into his head that he was divine and insisted upon having his divinity respected. For his impiety Callisthenes was condemned to die.

Aristotle interceded in his behalf. Possibly, in so serious a matter, he was importunate. He may have pointed out to Alexander the fact that his godship was highly questionable. At any rate, Aristotle was unable to save Callisthenes and only succeeded in bringing down upon himself the wrath of his former pupil and the threat that Alexander might yet prove his omnipotence by killing a sage.

5

This exchange ended relations between master and pupil. Still, while Alexander lived, the Macedonian party in Athens could hold its head up—and Aristotle along with the rest. But in 323 Alexander died—and the political pot in Athens boiled over. Antipater, who succeeded to the throne, was defied, and the Greeks rushed into the Lamian War.

Then it was that the enemies of Aristotle dared assert themselves.

The blow against the great scientist was struck by the chief priest Eurymedon, who charged him with having taught that prayers and sacrifice were worthless.

When that indictment was read Aristotle knew that the end of the fight had come.

For years he had shouldered his way against the hatred of the Athenians. Bent only on truth, he had left

in peace the ways that were Grecian, but the Greeks would not leave him in peace. Now it was over. Henceforth this scene would know him no more.

The priests had murdered Socrates. Aristotle said he would save the Athenians from further crime against philosophy and fled. Chalcis, where his mother's people had lived, welcomed him as a wanderer returned, but there was no cheer for the great teacher in this reception. For nearly a third of a century he had lived in Athens. There he was known and there were the friends whom he loved. There were his plants and his animals and his books. There were the scattered leaves of his writings. Here in Chalcis he was alone without the "tools of his trade"—and he was very tired.

Back in Athens his enemy Demosthenes was also tired and sadly discouraged.

So it came about that Athens's greatest orator and her greatest teacher, in the same year, 322 B.C., one in Athens and one in Chalcis, drank poison, and their busy troubled lives were ended.

6

Aristotle was a tireless writer, but the bulk of his work is lost; enough remains to stagger the imagination.

He wrote on metaphysics, logic, astronomy, meteorology, natural history, on "The Parts of Animals," "The Movements of Animals," "The Generation of Animals," on rhetoric, poetics, and politics. Who today would dare to attack that wide field? And he had none of the modern apparatus. He had no watch, no thermometer, no exact measure of weight and size, no microscope, no knowledge of gravity or of the weight of the air.

With almost nothing to guide him, he at first de-

stroyed the landmarks that existed. He demanded a sort of solitary grandeur. He wanted Aristotle to fill the universe and embrace all of the wisdom of mankind.

He denied the atomic theory of Democritus.

He scoffed at the hints of evolution put forth by Empedocles.

He repudiated the theory of Anaxagoras that the development of man's hand had sharpened man's wits. He said it was the other way round, and a bigger brain had called for a better hand.

He threw out Pythagoras's idea that the earth revolved around a central fire and flattered his ego with the old concept that the earth was the center of the universe.

He would not accept Democritus's idea that sensations center in the brain; he gave that function to the heart.

Yet in spite of this effort to parade his originality he was emphatically a scientist. His work justified Renan's observation that "Aristotle gave the world science." Certainly he gave embryology to the world. He discovered the early development of the heart in the embryo and he marched straight toward the great modern law, made famous by the embryologist von Baer, that in the embryo characteristics common to the genus appear first, traits of the species next, and individual markings latest of all.

## 7

He anticipated Gregor Mendel's work on heredity by raising a pointed question. A certain white woman married a negro. Her children were white, but among her grandchildren were negroes. Aristotle asked: Where was the black strain hidden in the white

woman's children? Two thousand years later Mendel answered that question.

In the nineteenth century Herbert Spencer stated, didactically, that the higher the development of the animal, the fewer the offspring. Aristotle, three hundred years before Christ, made this same discovery.

He said the line of life was from plants to the animals on the border line, through the lower forms to the higher, and so to man. Darwin, in the middle of the nineteenth century, developed much the same idea and called it Evolution. Aristotle was not an evolutionist, and he never got a glimpse of that great theory, but he was trailing an idea that, logically, should have led to Darwin's conclusion.

Aristotle practically created the science of Logic. People who find the subject interesting and would like to know more than this about it, should read John Stuart Mill, who touched it with genius.

In classifying animals Aristotle's powers had full scope. He was almost a pioneer in this field, and he did so well that his scheme lasted until Linnæus came along with something better. He divided animals into sanguineous and bloodless, the present vertebrate and invertebrate. In doing this work he got the idea of similarity between arm, fore-leg, wing, fin—a likeness now established by microscopic work on embryos.

He put men in a class with the viviparous—those animals that have enough vital heat to produce offspring without recourse to an egg developed outside the female's body. Still, Aristotle's man was distinct; he placed him in no subdivision that included anthropoid apes.

To all animals, at least to those that had the power of free motion, he gave a soul—but he reserved for man alone a sensitive and reasoning soul. This, probably, in

part accounts for his popularity during the Middle Ages.

8

Reproduction particularly interested him, and he found out a number of things about the lower animals that were true; but when it came to the human embryo he did not know, though he wouldn't admit it, and so wrote a pack of nonsense. Thus he says that the sex of the child is governed by the strength or weakness of the father. If he is strong the child is a boy; if he's weak, it is a girl. He formed no idea of sex cells, but attributed semen and ovum to surplusage; he says that the male property imparts movement to the ovum and guides and dictates the growth of the embryo.

Indeed, Aristotle had a low opinion of women—and he knew at least two of them intimately. The whole purpose of nature, he says, was to produce man—and by man he means the human male. Woman is an expression of nature's weakness. He admits that nature, perfect in its aims, makes mistakes because the material with which it works is occasionally faulty. Getting hold of a piece of raw material not good enough to make into a man, nature turned out a woman, and so bungled things that woman became necessary to the immortality of man—a condition that Aristotle bitterly regrets.

But it isn't necessary for modern women to take Aristotle too seriously. His knowledge of the female of the species was limited. He says, for instance, that man has more sutures in the skull than woman; that man has fewer ribs than woman, and woman has fewer teeth than man.

He thought populations should be limited—ten thousand to a city-state seemed to be about his idea. So, while he opposed infanticide, he favored birth control

by means of abortion. This was for the purpose, apparently, of giving the male a better chance—and he wasn't interested in how the women felt about it. He applauded the line, "Silence is a woman's glory."

It had been suggested that in the ideal state women should be trained as men were trained, so that the sexes might grow together. Aristotle spurned this idea. He didn't want women to become more like men; he wanted the differences emphasized that women might the more readily fulfil their one purpose—the mothering of male children.

"Young men are easily deceived, for they are quick to hope." Therefore no man, in Aristotle's ideal state, should marry until he was thirty-seven. Then he was to marry a girl of twenty. So they could grow old together—not for the sake of beautiful companionship, but because, with that difference in age, the reproductive organs would fail at about the same time.

9

Aristotle's god was an intangible, remote something, dragged in simply to set the universe going. He was the Mover without himself experiencing motion. Having imparted motion to matter, he could retire from the scene. And did.

The last word in physics will tell you that as far as motion was concerned, this old Stagirite, three hundred years before Christ, made a shrewd guess. Material substance, the things you see and touch, the extra wise ones say, in this year of grace 1929, are only vibrations—movement set up in the atom by the electron flying about in its orbit. Electrical? Maybe. Everything in the universe merely an electrical manifestation? Even if that's true, "things" remain real, just as they did with Aristotle's Mover who was unmoved.

But this motion was not imparted to the earth. The earth stood still, but it was spherical because the sphere approximated to the perfection of the circle—the form that stood highest in the eyes of Nature. Around this earth the sun, moon, and planets moved. All his life Aristotle trusted his eyes: he couldn't believe they deceived him when he *saw* the sun rise.

Though he listened to weird tales of travelers, and set down their reports for facts, he seems not to have been really interested in geography. He tells of strange and far-away monsters, but he does not describe the other side of the earth or try to picture what happened to the sun when it disappeared below the horizon.

Expanding his theory of motion Aristotle saw the world in a state of constant change. The endless circle of the shrinking sea and the falling rain; the coast sinking at one point and rising at another; the toppling of mountains and the building of new heights; the green of spring and the fading of autumn; the plains becoming desert and the deserts becoming plains; the rise and the fall of nations; the birth and the death of man—all of this he saw with the eye of a cosmic philosopher, and all of this he set down with the hard understanding of one who has seen, in the unfolding of a rose leaf and the disappearance of a drop of dew, the endless repetition of life in Eternity.

10

Aristotle studied animals, and he cut them up to be sure he didn't miss anything. Probably he would have done the same thing to the human body if law and religion had not joined to put that notion out of his head. As a result he didn't know much about his own inner organs, but he was fairly intimate with the hidden parts of five or six hundred of the lower animals.

He was perfectly willing to guess if he didn't know, but he would far rather know than guess. So, when he said there were some species of shark that produced their young alive and did not lay eggs, he knew what he was talking about. For several centuries this shark story was told as an evidence of Aristotle's credulity. It was supposed some sailor had convinced him with a rare fish story. But at last it developed that Aristotle was right.

It was a common belief, before Aristotle and since, that the embryo contains the future animal in miniature. The human fetus, it was supposed, would, if it could be seen, look exactly like a newborn baby—only very small—"about the size of a little finger." Aristotle upset this idea—but he did not kill it. There were many people living in the nineteenth century who believed it; maybe there are people now living who believe it.

Aristotle watched the development of the chick in the egg, and he saw the germ grow, take on form, add new parts. "The heart appears," he writes, "like a speck of blood in the white of the egg [after three days' incubation]. This point beats and moves, and from it two vein-ducts with blood in them trend in a convoluted course; and a membrane carrying bloody fibers now envelops the yolk. . . . A little afterwards the body is differentiated, at first very small and white."

In this study of the egg he saw all that could be seen without a microscope. But having given this fine and accurate description he passes to the statement of an error that lasted for centuries and died hard at the hands of Spallanzani, the Italian embryologist of the eighteenth century.

Aristotle saw things come into existence where, as far as he could make out, there had been no life. So, he said, among the lower forms spontaneous generation

occurs. For two thousand years his word was taken as final. Probably boys still think a horse hair, put in rain water and left in the sun, will turn into a snake. Anyway, they believed that forty years ago. It won't, of course, and ever since Spallanzani, or at any rate Pasteur, scientists have felt sure that only life begets life and that not even the tiniest germ comes into being without some kind of father and mother or something just as good.

Aristotle had another pet error that lasted until the time of Galileo and was supposed by everybody to be a statement of truth. The rate at which objects fall, he said, is in proportion to their weight. Ten pounds of iron will thus fall ten times as fast as a pound of iron. That seemed reasonable, because the big weight would make a bigger hole when it hit than the small weight. A big man comes down harder on the ice than a little man. Everybody knows now that Aristotle was wrong. The amazing thing is that he should have been satisfied to be wrong. He liked to get a lot of data and make his theory afterwards. But in this case he made no effort to experiment. He believed what he was told—and passed the error on.

II

Don't remember Aristotle for his mistakes. Darwin did not. The great evolutionist of the nineteenth century was not too big to admire the Greek naturalist of whom he says:

"Linnæus and Cuvier have been my two gods, though in very different ways; but they were mere schoolboys to old Aristotle."

In more fields than one, Aristotle was a pioneer. As he says:

"I found no basis prepared; no model to copy. Mine

is the first step and therefore a small one. You, my readers, will acknowledge what I have achieved and pardon what I have left for others to accomplish."

A small step? He ruled like an absolute monarch until Galileo, an Italian of the first years of the seventeenth century, rebelled against the tyrant—and was not at once struck dead for lese-majesty. Since then Aristotle has had to take his chances with the rest. At all times he has crowded the front runners. As science has moved ahead, gaining a new position, it has often enough found Aristotle occupying the post and waiting for the modern giants to come up.

This is not surprising if we remember that Aristotle was:

The first of the world's great biologists;
The first embryologist;
Creator of the science of logic;
The first classifier in the realm of natural history;
The first great inductive reasoner.

Is it any wonder, then, that no other man, in science, has exercised so great an influence for so long a time?

*Chapter Six*

# ARCHIMEDES

ARCHIMEDES, the cleverest juggler with figures Greece ever produced, was born at Syracuse, on the island of Sicily, in 287 B.C. The glory of the city-state had passed before his birth, and during all of the seventy-five years of his life war and the alarums of war were about him. He was only nine years old when Pyrrhus, king of Epirus, came to Syracuse to help fight the Carthaginians who occupied the western half of the island and who had been having rather the better of an age-old strife. He was eleven when Pyrrhus, disgusted with the petty jealousies and intrigues around him, shook the dust of Syracuse from his feet forever.

It may have been at about that time that the boy Archimedes was sent to school at Alexandria, which, robbing Athens of its prestige, had become the intellectual center of the world. Of his life there absolutely nothing is known. There are hints that suggest many years spent in study but what kind of boy and young man he was will now never be known. There is no gossip that loads him with the sins of youth. His later life indicates a serious and profound mind, given to sly humor.

The chances are even that he was connected with the royal family. Many of his writings are lost, and even if they were all in existence probable questions about his life would remain unanswered. Anyway he surely had a home in Syracuse and there's no harm in sup-

posing he had a wife. It's highly unlikely that so absent-minded a man of good family—and famous—would be able to keep single. He was the kind of man women would want to take care of—for his own good.

2

His fame spread. All the world knew Archimedes for his cleverness as an inventor. He was the first Yankee, and his ingenuity has elbowed and fed every Yankee who has lived since his time. But Archimedes sneered at his mechanical "toys." Invention was beneath the dignity of a real mathematician. Or so he said. But he was proud of his skill, just the same. He never boasted of his work in mathematics. In that field, where he must have known he was a master, he was modest, diffident. He writes of a friend whose early death he mourned:

"Conon died before he had time to investigate these theorems. Otherwise he would have discovered and made manifest all these things, and would have enriched geometry by many other discoveries besides."

Yet the same man who could write thus modestly of his real life's work could turn arrogant and boast:

"Give me a place to stand on and I will move the world."

"You're a boastful fellow," said King Hiero. "Prove your words by moving for me some great weight."

Archimedes was the only one in all the world who knew the principles of the lever and pulleys. He saw his way so clearly that it was mere child's play to him. Now just at that minute Hiero had a serious problem on his hands, for the ship he had built for King Ptolemy could not be launched. All the men in Syracuse had worked at the job, but their combined strength and ingenuity had not been equal to the task.

"I'll launch your ship for you," said Archimedes, and he went about devising a system of pulleys so that with slight effort one could move a great weight. When it was all ready he put the end of the rope in Hiero's hand and told him to pull. The king did so, and the ship moved steadily down into the water.

It must have looked like magic to the king and his subjects. The king immediately issued a proclamation saying:

"From this day forth Archimedes is to be believed in everything that he may say."

It isn't on record that Archimedes took unfair advantage of this royal edict—and probably it gave him very little advantage in his slight differences with his wife. He must have been constantly getting into trouble with that good woman—and she must have been very, very patient.

3

What could one do with a man who when you said, "Dinner's on the table," didn't even hear you, but went on drawing triangles, squares, and circles in the ashes on the hearth? She had to watch him all the time because when he was rubbing oil on himself, in lieu of bathing, he'd forget what he was doing and there he'd lie drawing diagrams on himself in the oil!

But even that was better than sending him to the public bath. She stopped that after the terrible spectacle he once made of himself.

It all started with the king's new crown.

4

Hiero wanted to know if any alloy had been mixed with the pure gold. He asked Archimedes to find out. That was a poser. Apparently there was no way of

reaching a solution. Just at the moment when he felt he should have to tell the king it couldn't be done, Archimedes stepped into his bath. The water rose. When he sat down it ran over the edge. At the same time he noticed that the more nearly he submerged, the lighter his body seemed to be. "Eureka," he cried and sprang out of the bath. He knew how to weigh the king's crown, and his first thought was to rush out to demonstrate it.

So he went right out into the street. It must have embarrassed his wife.

For thousands and thousands of years men had seen the water rise when they stepped into it. For thousands and thousands of years they had known that the body was lighter, or felt lighter, in water than out. But these two facts had not meant anything to them. They meant something to Archimedes. When he found that the water displaced by the crown did not weigh as much as the water displaced by gold weighing the same as the amount of that metal given to the goldsmith by the king, he knew that base metal had been substituted. He told the king he was sure it would be easy to get a confession from the goldsmith. It was.

That was the first move in the development of hydrostatics and led to the discovery by Archimedes of a number of fundamental theorems published in his book "On Floating Bodies."

At some time, probably during Archimedes's stay in Alexandria, the Egyptians appealed to him for help in handling the water of the Nile. They wanted some simple way of giving it a fairer distribution. The result was the development of Archimedes's screw. Probably this consisted of a tube wound in the form of a long spiral, set in the water at a very easy grade, and so arranged as to be constantly revolved on its long axis.

It was so set that the submerged end of the tube would clear the surface on each revolution, and the water be lifted. Gravity is actually the propelling force in this apparatus.

In his leisure moments Archimedes busied himself inventing a sphere so constructed as to imitate the movements of the sun, moon, and five planets. The contrivance was operated by water and was made with such accuracy that it would even show the eclipses of the sun and moon.

5

Archimedes was growing old. Conon, the friend of his schooldays, was gone. His friend King Hiero was gone, and in his place ruled the rash and vain Hieronymus. This young man broke with precedent and threw the fortunes of Syracuse into the scale with Carthage against Rome. That was the beginning of the end. It was not long before an army under Marcellus was hammering at the city's gates while Roman ships blocked the harbor.

It is easy to believe that Archimedes did not favor the union with Carthage, but now that the harm had been done he drew on the resources of his genius to help his countrymen.

And he helped them. Almost single-handed he kept Marcellus at bay. He made the Roman engineers a laughing stock. They were little children by comparison with this man who "with something to stand on was ready to move the world."

When you see a crane swinging a railway locomotive into the air, remember that, in defense of Syracuse, two thousand, one hundred and fifty years ago Archimedes used a similar apparatus. With his cranes, he grappled the Roman ships, raised them high in the air, and let

them fall to smash to pieces against the waters of the harbor; or he swung ship and crew over the wall and lowered it to be dealt with by the Syracusians.

He arranged catapults that hurled great rocks against the Roman ships. He devised machines for throwing showers of metal and small rock through holes in the walls.

Indeed, he made things so hot for the Romans that Marcellus taunted his men saying:

"When will you make an end of fighting against this mathematician, who, sitting at ease by the sea, plays pitch and toss with our ships, and by the multitude of missiles that he hurls at us outdoes the hundred-handed giants of mythology?"

But Marcellus found that his men were in terror of their lives at the hands of a mere scientist, an old man with a sly sense of humor. Things got so bad that a bit of rope thrown over the wall was enough to cause a panic among the Romans. So Marcellus did the only wise thing; he gave up all idea of taking the town by assault and settled down to starve out the enemy. This was a plan that even Archimedes could not thwart.

At last in 212 B.C., Syracuse surrendered, and two years later Rome held all of Sicily.

6

"Spare that mathematician," Marcellus told his men as they rushed to the sack of helpless Syracuse. When the attack on the place settled into a siege, Archimedes returned to his studies. At the right moment he had come out of his dreams, and had put powerful weapons in the hands of his friends. Then he returned to the world of abstract thought—and forgot all about the war.

There was no smoke of combat in those days, and the

air over Syracuse was clear—clear and still, for the small noises of defense and attack were not enough to disturb a philosopher. Of what was he dreaming in those last days? What problem was he pondering? Had he a new theorem involving a sphere circumscribed by a cylinder? That was his pet! That he wanted to be his epitaph!

So he dreamed, an old man with his head full of squares and cubes and spheres—and strange and beautiful angles. Maybe he pondered the relation of the earth to that vastness that curved above him. This earth, which he knew was round and which, he believed, circled the sun, was not to him the huge and dominant thing it had been to Aristotle. To Archimedes it was a small stopping-place in an enormous universe. Even in his astronomy, this mathematician was a modern.

Did he hear the shouts of the Romans as they invaded the city? Did he hear the death-cries of his friends? Probably not. He may have been, in that awful moment, dreaming of the Force that let loose the earth and set the planets whirling in their appointed paths. He was drawing, in the dust of the flagstone, a pattern of the stars in their courses.

A shadow fell across his work; a foot disturbed his diagram.

The intrusion snapped him back to earth.

"Stand away, fellow, from my diagram," he shouted.

As always, Ignorance, infuriated, swung the sword. . . .

"Marcellus," says Plutarch, "was most of all afflicted at the death of Archimedes." And rightly so. The others who fell on that day were as grass of the field; but it required nearly two thousand years for

Nature to produce in Isaac Newton the equal of the dreaming Yankee of Syracuse.

Years later, when Cicero was questor in Sicily, he found a neglected tomb, overgrown and weed-hidden, which bore as sign a cylinder circumscribing a sphere. Cicero restored that tomb; he knew that all that was mortal of Archimedes was resting in that obscure spot.

7

Archimedes ties up closely with the every-day life of the modern man. The laws he found and proved are in constant use everywhere. For eighteen hundred years after his death the world made no advance in the theory of mechanics. When it began to progress it was supported by the facts Archimedes had given it.

Out of the episode of the king's crown he discovered and stated the law: A body immersed in water loses in weight as much as the water which it displaces weighs.

Out of this first discovery grew his whole science of hydrostatics—a science of which he was the originator. Every man who builds a ship or depends in any way upon the buoyancy of water accepts as final the primary facts of "floating bodies" as given by Archimedes. When you speak of the displacement of a ship you mean the weight of the water that would be necessary to fill the space occupied by the hull of the boat.

Another of his hydrostatic laws says: A solid lighter than water, forcibly immersed, is driven upwards by a force equal to the difference between its weight and the weight of the water displaced.

In two books on "Floating Bodies" he developed his laws, and the shipbuilders of the world can thank him for the correctness of the principles upon which they lay down their hulls.

In mechanics he also formulated laws that are basically sound and in constant use. "Weights which balance at equal distances are equal." "Unequal weights at equal distances will not balance." "Unequal weights at unequal distances will balance, the greater weight being at the lesser distance." These laws are simple and self-evident, yet they are the basis of all our mechanics whether it is operating an elevator, a steam crane or with a system of pulleys and ropes hoisting a steel safe up to the twentieth floor.

8

His work in geometry proves Archimedes was one of the world's greatest mathematicians. He was no worker-up of old material. He was constantly on the trail of something new. He attacked the sphere, conic sections, spiral—indeed, he came as near discovering differential calculus as was possible without a knowledge of algebra.

He wrote one treatise, "The Sand-Reckoner," in which he proved that he could number the grains of sand necessary to fill the visible universe. He sent this little book to King Gelon, and apparently his Majesty was willing to take the demonstration as final and not ask for a graphic illustration. This of course was merely as Draper says, "the sport of a geometrical giant amusing himself with his strength."

In order to see just how big this man's head was when it came to figures, it should be remembered that the Greeks had no number characters as we have and did not use the cipher. The first nine letters of the alphabet, accented, stood for the figures from one to nine; the next nine from ten to ninety, and the next nine from one hundred to nine hundred. They wrote their numbers as we do with the largest on the left, but

they knew nothing of decimals, their fractions were cumbersome, and their processes of division and multiplication were laborious.

These difficulties were as nothing to Archimedes. Imagine what he would have done with the Arabic system and the algebraic characters! Yet in spite of handicaps he was able to state and prove, at least in part, the "Cattle Problem." This problem, probably, was as much satire and fun as mathematics.

Apollonius, a rival, had come nearer to hitting upon the correct ratio of the diameter to the circumference of a circle than Archimedes. So this Yankee of Syracuse decided to give Apollonius something to keep him busy. In that spirit he sent out the Cattle Problem, which calls for the discovery of eight unknowns, each of which must obviously be a very great number.

"Compute the number of the oxen of the Sun," Archimedes writes, "giving thy mind thereto—if thou hast a share of wisdom. . . . It is required to find the number of bulls and cows of each of four colors. When the white bulls joined in number with the black they stood firm with depth and breadth of equal measurement; and the plains of Thrinakia, far-stretching all ways, were filled with their multitude."

Amthor, the German mathematician, worked on it and arrived at some curious conclusions. He found that to give the number standing for one of the unknowns would require fifty lines with fifty figures in each line, or eighty-two and a half pages a little larger than the average book size. To write out the answers for each of the eight unknowns, then, would require a volume of six hundred and sixty pages!

*Chapter Seven*

# GALEN

PERGAMUS, in Mysia, isn't much of a place now. About twenty thousand folks live there and make a living by trading between the East and the West. It never was large, but it had some importance about 197 B.C. After that it began to decline, and in time it became famous for only one thing: the site of Satan's seat, as described by St. John in Revelation. Satan's Seat probably was the beautiful throne erected by the pious Greeks to Zeus.

Pergamus was founded by a eunuch, Philetærus, who, sent there to guard a fortune, rebelled against his master and set up a state of his own. But the fact that Pergamus lingers in history is because of St. John, and of Galen, the last of the great Greek doctors.

Galen was born at Pergamus in 130 A.D. Nicon, his father, was an educated and cultured Greek, probably an architect. Galen's mother doesn't get so flattering a record. She looms out of the past as a second Xanthippe —a shrew, a nagger. Maybe there was a reason for this. Her husband may have been a bit of a rounder, and as her son turned out to be a genius, life couldn't have been very easy for her.

When Galen was twenty, Nicon died and the boy set out to see the world and learn medicine. There is no careful record of his travels, but he certainly was in Smyrna and studied there. He was also in Alexandria and heard lectures on medicine by Stratonicus and

Æschrion and on anatomy by Heraclianus—famous teachers of the time.

What kind of youth did he have? What romance? One guess is as good as another, because Galen never told. At worst, he must have been fairly industrious, since he was only twenty-eight when he returned to Pergamus and started practicing medicine. Of course he was successful; he was head and shoulders above his contemporaries. For some time he was busy getting experience, and during this time there is no mention of his mother.

Pergamus was too small a field for this genius, and he set out for the New York of the times, that is to say, Rome. At first he was rather coolly received, for he would have nothing to do with any of the orthodox schools of medicine. Hippocrates was his hero, and he tossed aside all that the moderns tried to tell him.

However, luck was with him. And when he healed Eudemus, supposed to be afflicted with an incurable disease, he became famous. Rome accepted him—and paid him high fees. A rich lady whom he attended for two weeks paid him the equivalent of $2,000 for his services, and money was worth more then than it is now.

2

Marcus Aurelius, gentle philosopher-king, had to follow the fashion, and Galen treated his majesty for the stomach ache, following a too hearty diet of cheese, with satisfactory results, apparently—for Marcus, when he went to war, put his son Commodus in Galen's charge.

All of this did not hurt Galen with the fashionable world, but it brought out severe criticism by his brother doctors. Maybe they were jealous of the handsome

Greek, who dressed like a fop and worked like a stevedore. Galen could afford to ignore these critics as long as the court was with him.

He was too busy to waste much time on them. He studied constantly, and not from books. Nature was his school. He was deeply interested in knowing what went on inside the human body. How could he find out? To dissect a dead man was a capital offense. Even the influence of the court couldn't save Galen if he committed so heinous a crime. But Galen was resourceful. He reflected that there wasn't such a lot of difference between men and monkeys. So he studied human physiology and anatomy by cutting up monkeys, or if he ran short of them he tackled pigs. In this way he learned a good many things of which his contemporaries were blandly ignorant.

Aristotle had taught that the arteries contained air. Galen's work showed him this was nonsense. The arteries contained blood. In fact, he just missed discovering the circulation of the blood. His dissecting lacked something in technique, and so, while he found there was a circulation through the lungs and a circulation in the veins, he never connected the two. His venous system seemed to originate in the liver, and he was not at all clear as to how the blood got back—the existence of capillaries always evading him.

Also he had a queer notion about the heart. He found the valves, but he did not associate them with the movement of the blood, and it never occurred to him that the heart was a pumping engine.

These false theories wouldn't have mattered if Galen had not so completely overshadowed everyone else that his word was taken as final for many centuries.

As to the bones, he was better informed. Luck favored him there. On a mountain he came across a

skeleton of a robber who had been killed. Galen studied those bones.

From his apes he got a fair notion of the muscles and nerves, but naturally his work here was far from accurate. He taught that nerves of sensation originated in the brain, and motor nerves in the spinal cord. He was among the first to find out that there are two kinds of nerves, and he wrote intelligently of this discovery. He described the organs in the chest and abdomen and knew pretty well the function of each.

3

In spite of his practice and his studies, Galen found time to write down all that he had learned and a lot that he hadn't. In all he wrote seventy-eight books and fourteen essays. He had nine books on anatomy, seventeen on physiology, six on pathology, sixteen on therapeutics, and thirty on pharmacy.

You will notice he wrote nothing on obstetrics. The birth of a child was something in which a really wise man had no interest. That was a condition that lasted for many, many centuries. Indeed, it was only yesterday that the work was taken away from the midwife—if it really has been taken away from her.

With all this writing, Galen mixed up a lot of silliness. He had a theory for everything and he carefully wrote down all his theories. One of his most sweeping and inclusive theories said that everything in nature shows an intelligent design and is evidence of the goodness of the Creator. It never occurred to him that life is very greatly modified by the action of the two great forces: heredity and environment.

He had three other theories, set down by him soberly as facts, that for centuries raised hob with the medical profession.

First, that the blood gets "natural" spirits in the liver, "vital" spirits in the left ventricle, and "animal" spirits in the brain. The whole organism, he said, was animated by the "pneuma." This apparently is what is now called the spirit or soul.

Second, that the blood passed from the right to the left ventricle through imaginary pores in the dividing partition.

Third, that pus must form in the healing of wounds, a theory that was long afterwards known as "healing by second intention." This foolish notion held surgery back for a long time and claimed thousands and thousands of victims.

4

Galen was a born wanderer, driven by a fierce thirst to know. He stayed in Rome longer than anywhere else, but not even Rome could hold him permanently. A vague rumor says he fled the imperial city to escape the plague. Not likely. Certainly his idol, Hippocrates, did just the opposite.

At any rate he gave up his practice and set out on far journeys. No one knows all the places he visited, but he is seen clearly on the Island of Lemnos, drawn there by reports that the mineral, *terra lemnia,* had great curative properties. It is unlikely that he stayed there long, but it is reasonably certain he never revisited Rome.

His last years are shadowy. There are faint signs of him here and there, delving at nature, writing, telling his friends of his discoveries—going on into the twilight. So he fades out. Even the date and place of his death are uncertain. It seems probable that he died on the island of Sicily at eighty years of age.

Strange that a man who had shone so brightly in

Rome's eyes, who had flaunted it so near the throne, should have passed into such absolute obscurity during the last twenty years of his life!

5

Though Galen vanished, Galen's work and influence lived on. After him for a thousand years there arose no master. In time he became legendary, his name fit to conjure with. He became more than that: he became infallible, divine. In the popular mind he was canonized. For a thousand years he ruled with a rod of iron. To the Dark Ages he was an oracle. He had seen all, known all. He left no secrets. To learn Galen was to learn the perfection of medicine. He was to the profession what Aristotle was to the scientists.

For a thousand years the world lay at his feet, giving to his errors the same veneration it paid his truths. It is because of this adoration, this blind worship, that Galen has been endowed with immortality. Unmeaningly, he dealt medicine many hard blows, and he lives today largely because of the reverence paid his errors.

## *Chapter Eight*

# PTOLEMY

ROME'S rise was the death of science. Greece, in decline, ceased to breed genius. Athens languished, and the center of learning was pushed to Alexandria. There the grammarian flourished, and form and symbol crushed originality. It was exactly as though, with the death of Galen, a curtain were lowered over the intelligence of man.

There were efforts to push on, but they were futile. Compilation and criticism took the place of research and deduction. The spirit passed. It did not shine forth even in Ptolemy, against whom the world still holds a grudge.

Ptolemy gets into the picture because he crystallized an ancient idea—an idea that fitted biblical lore, just then coming into the West on the lips of Jewish fanatics. Ptolemy had a chance to choose between the right and the wrong. From the time of Pythagoras on, the notion of a world circling the sun was in the minds of scientists. The masses, of course, believed the world stood still while the sun and stars flew around it. Our astronomer, trained in Alexandria in the world's learning, considered these two ideas, weighed the evidence in favor of each, and chose the wrong.

With all the authority of his great learning he voiced, as final, the dictum: The world stands still while around it revolve the sun and stars. He introduced weird circles and crystalline globes in an effort

to account for the phases of the moon and the shifting positions of the planets. He did it all rather well and, when at last he died, he had no doubt that he had solved forever one of the great natural problems.

2

Nobody knows much about Ptolemy. He had no ready-writing biographer, and the details of his life are gone. Probably he was born in Egypt, of Greek parents, either late in the first or early in the second century, A.D. One gets the time from the date of his first recorded observation of the stars—127 A.D. His last record was made in 151. What he looked like, how he lived, who his parents were no one now knows. Maybe he belonged to the royal house of Ptolemy—a student prince. But at that time in Egypt the name Ptolemy was about like Smith in America. That he studied at Alexandria is certain, because that was the only place in the world where he could have learned the things he knew.

3

Ptolemy made a fool guess at the riddle of the universe, but he was no fool. On one thing, at least, he was right: he said the world was round and hung in space with no props to hold it up.

This was rank iconoclasm. It was knocking away the underpinning and, to the man in the street, sheer nonsense. The world was flat, as could be seen with even the poorest pair of eyes, and there were some sort of pillars at the edges to support it. The foundation for the pillars? Oh, well, it was enough to know that the earth wasn't going to fall. So both of Ptolemy's conclusions were thrown out by the public until Columbus dreamed a dream and proved the truth of it.

4

When he came to consider what made the sun rise and set, Ptolemy went wrong. His error here was due to another problem he couldn't solve. He seems to have felt that the world ought to move. The simplicity of this arrangement appealed to him. The earth could turn on its axis a good deal easier than the sun and stars could race around the heavens at an incalculable speed. But if the world moved what about the furious wind that would sweep everything off into space? There wasn't any such wind. The air was placid, or reasonably so, and that, for him, killed the idea of a revolving earth.

Ptolemy had a notion there was something silly about his theory, but he couldn't convince himself it was basically wrong. The bad feature, as he saw, lay in the speed at which the sun and stars would have to move in making their trip around the world every twenty-four hours. He got around this by talking of a great sphere, in the inner surface of which the stars were set like jewels. This sphere, with the stationary earth at its center, whirled itself around carrying the heavenly bodies along with it.

When it came to the planets, or wanderers, he was momentarily stumped. They were not set in this great and convenient sphere, but went racing around, doing about as they pleased and upsetting the whole fine theory.

That made him give them motions of their own about a fixed point and thus epicycles got into astronomical jargon and stuck there until Copernicus came along and knocked them out.

So Ptolemy, having done the world all the damage he could, sank into the grave, but his theory went

marching on. Even today you'll have no trouble finding people who think his ideas are sound and sensible, and many of them would still like to know what holds the world up.

*Chapter Nine*

# INTO THE DARK AGES—AND OUT

AT any rate, Ptolemy had told the public what it wanted to believe. The public believed it. The evidence was before their eyes. They could see the sun climb up in the morning and the stars sweep across the sky at night. To them this evidence was final. Besides it was what they wanted to believe. It tickled their vanity. This world of theirs was far and away the greatest and most important thing in the universe, and to that thought they clung.

Christianity swept in. Its teachings meshed perfectly with the Ptolemaic theory. Man and his home, the world, were the results of direct, special creation at the hands and mind of the Ruler of the Universe. It was all very simple and clear. Man was exalted by his own interpretation of nature.

The idea crystallized; it became a tenet of the church; to doubt it was heresy. For fourteen centuries no one of importance did doubt. For fourteen centuries. Note the power of a false idea. The church cemented itself on a firm foundation; it spread over all Europe; it added temporal to spiritual power. It flourished—and science, even learning, died.

Rome triumphed, but you can't look to the Romans for science, for an advance of culture. The degeneration, roughly matching the fall of Athens and the rise of Alexandria, gained speed swiftly during the first

centuries after Christ. The twilight deepened, until in the fifth century all light vanished and darkness settled over Europe.

Rome, as a world-power had passed. The church had gained a militant position. Out of the North had come the hordes of barbarians, crushing culture, destroying schools, beating back civilization. But, though they wiped out pagan attainments, they halted at the foot of the cross.

There was performed the miracle of the church. These wanderers were molded by her hands; they were guided by her love; they were slowly enlightened by her policy. All that is Europe today lay in the heart and brains of those invaders. When they rushed across the Roman borders, only two courses were open to civilization: exterminate them or civilize them. They could not be exterminated. They were much more likely to exterminate the peoples of Southern Europe.

The church was the only institution capable of influencing them. She set herself the mighty task of conversion. It was a death grapple. The hordes must kiss the cross or the church was doomed. They kissed.

2

But the struggle threw all Europe into chaos and brought about the eclipse that is called the Dark Ages. Don't speak slightingly of the Dark Ages. They were the birth pangs of the twentieth century. During them the wilderness of human ignorance was slowly invaded.

If no great tracks were cleared, at least trails were blazed. Those who entered the Dark Ages as barbarians reappeared, with the revival of learning, as men and women set in the ways of culture and fired with a thousand Why's.

Alexandria was burned; schools disappeared; pro-

fane learning was stigmatized as an insult to God. All wisdom was in the Bible, and all knowledge was in the possession of the Church Fathers—men more ignorant of science than any ten-year-old boy is today. The Greek writers were banned and then, for centuries, forgotten.

There was no philosophy; there was no mathematics; medicine was dragged down from the high estate toward which Hippocrates and Galen had pointed it, and knaves sold amulets and bits of writings to protect the faithful from the ills handed out by the devil. Sickness came either from Satan, who was tormenting the faithful in an effort to make them curse God, or it came from God as a visitation for sin or as an affliction to purge the soul. In either event there was nothing to do about it. To attempt to cure it was to insult the wisdom of the Deity and bring down punishment for blasphemy.

As a result Europe was a cesspool that reeked with contagion. Plague after plague swept the cities, claiming thousands upon thousands of victims who died horribly—with the name of God mumbled in their ears. The devotees of an exacting faith were too busy preparing for a self-created heaven to notice the filth through which they waded.

3

Astronomy was perverted into a silly superstition, and the astrologer grew rich on the ignorance of those who thought the stars were mindful of the lives of little men and women. The astrologers claimed to be able to foretell the future of the suppliant and to give help to struggling creatures. There are always people in the world who are willing to coin fear and superstition into gold.

Chemistry was caught in the general crash. It had never risen very high, but it never sank so low as it did during the Dark Ages. A strange madness fell upon men. Gold blinded them. Picking up the merest smattering of chemistry they attempted to perform miracles that still baffle the skilled genius of the twentieth century. They were so unthinking that the practically impossible seemed to them simple. They set out deliberately to change base metal into gold. Fabulous riches and power awaited the man who learned this secret. All that was necessary to insure success was to discover or compound the philosopher's stone. The search was world-wide—and the result was weariness and vexation of spirit.

No one ever found the philosopher's stone. Many claimed to have done so, and more than one fakir declared he could turn lead into gold. No one ever did it, though you'll have no trouble finding people who still think the secret may be rediscovered. These alchemists, who boasted of their success, wrote hundreds of volumes in which they said they described their process and revealed their secrets. Their writings, without exception, are as confused and unintelligible as the ravings of a madman.

4

Meanwhile the sale of relics became a vast business—and highly profitable. Bribes, designed to beat hell and insure a pass to heaven, were freely offered and freely received. Churchmen defended this by asking, "Did not Jesus accept gifts from the wise men?" Politics invaded the church. Morality was only a word.

Strange and new doctrines got into the creeds. Some of these were concessions to northern idolatries. The Germanic tribes needed some visible image before

which to kneel. Demanding an intensely personal god, they were given a trinity.

But the effect of all this was not wholly bad. It may well be that it worked for a final good.

Always in monastery cell or priest's home, one could find, here and there, a scholarly monk, a wise priest. At no time was the world without its good men. It was they who saw Rome as she was, and not infrequently there came the "voice of one crying in the wilderness." They pointed the finger of shame at the Holy City and without fear denounced the conduct of popes and cardinals. Their words lingered in the minds of the northern peoples. In their denunciation lay the sleeping spirit of revolt. Time only was needed.

5

Meanwhile, out of the East had come a new power. The Moors swept into Spain. They brought with them religious fanaticism, a burning zeal to proselyte, and a culture superior to anything then in Europe. In conquered Spain they set up a permanent government and built cities that were the admiration of the world.

They established schools into which their tolerance admitted Christians. Their scholars hunted the past, unearthed the Greek classics and translated them into Arabic. From India they had obtained the Arabic numerals, and these passed on to Europe along with algebra and a highly simplified system of notation for that science. If they produced no figure of heroic proportions, they did give the world great scholars at a time when even an averagely well-informed man was a curiosity.

When the intellectual leaders of Italy and the Germanic peoples were debating, seriously, such profound questions as how many angels could stand on the point

of a needle, Assamh, a Moor, killed in battle in 720 A.D., was writing on topography and noting, through wide travels, the changes in flora and fauna due to elevation. A little later, near the close of the ninth century, Mohammed Ben Musa was telling his pupils about algebra and substituting the sine for the chord in trigonometry and inventing the common method of solving quadratic equations. At this time probably not ten men in Europe had ever heard of an equation.

In the year 1000, Ebn Junis, beating Galileo to the same idea, first used the pendulum in measuring time. Before that the Moors had only clepsydræ, water clocks, but these they had brought to such perfection that they did their work with rare accuracy.

6

While Europeans were living like pigs and dying like flies, and pinning their hopes for health on shrines and relics, Avicenna (980–1037) was teaching the Moors medicine and philosophy. He was a surgeon as well as a doctor and he has left a description of the instruments then in use and his methods of treatment. He was a student, free of the superstitions that were clouding Europe.

Alhazen, greatest of the Moorish school, is something of a mystery. It seems impossible that some of the writings attributed to him can be authentic. He knew too much. He should have come with Newton—or later. Those who are interested have tried to sort the real from the false without much success. Some of this doubt is due to the backward European's jealousy of the Moor's advanced position. It doesn't really matter. Some one, Alhazen or another, about the dawn of the twelfth century or soon after, made startling contributions to the world's knowledge.

It's agreed that Alhazen wrote on optics. It was he who corrected an age-old idea as to how men see. The Greeks thought the stimuli came out of the eye to the object, thus making it visible. Sounds silly, doesn't it? But the wisest of the ancients thought that was the only possible explanation.

Alhazen hit upon the truth—that rays of light come to the eye from the object. He went further, and said the retina was the seat of vision and that the impression made there passed along the optic nerve to the brain. He was right; but how did he know this? By dissecting a human body? That was against the law. No matter. Alhazen was ready to face death in order to know.

The whole question of light interested him, and he was the first to realize that we don't quite see things where they are. He worked out this refraction, and for the first time in the history of the world the curvilinear path of a ray of light was charted.

In the part of Alhazen's writings that Europeans question, he appears to recognize gravity and to know that it diminishes with distance. However, he did not know that this diminution is as the square of the distance. Also, and worse, he limited gravity to the earth, not having the vision to see this power as universal.

He was an evolutionist, or whoever wrote under his name was, and he described the progressive development of animal forms seven hundred years before Darwin was born.

7

This is only a snapshot of the Moorish movement. After all, these scientists did not, as did the Greeks, contribute largely to European progress. When Europe woke up, she went to antiquity for her ideas or swung

into intensive research and experiment, forgetting or ignoring the Moors. They were, because of race, religion, and later political failure, outside the main current of world advance. They are still outside that current; but they deserve this tribute for keeping the light burning before the altar of science when all the rest of the world was lost in darkness.

8

Now consider the condition in Europe, outside of Italy and Spain, when the faint light of a rising sun promised the end of the Dark Ages.

Paris and London were crowded heaps of hovels—with thatched roofs, straw on the floors and an opening above to let out the smoke. There wasn't a foot of paving in any northern city, and when it rained the streets were quagmires into which one sank to one's ankles. There were no street lights, and the late reveler carried torches or crude lanterns. There was no sewage disposal, no hospitals, no schools, no roads. There were only filth in the homes, mud in the streets, and pestilence in the air.

The Europeans were content to wallow in the mire—and dream of heaven. They were covered with hair shirts and vermin, but they prayed for purity of soul. They fought and robbed and murdered in the name of the Galilean. They scratched their tiny fields with a wooden plow, and their finest equipage was an ox cart. Four oxen were a sign of royalty, and as they shambled through the mud the peasants humbled themselves. Their religion was as somber as their words except when they decked themselves in flowers and celebrated pagan rites, not always chaste.

They knew nothing of mathematics, of geography, of medicine, of astronomy. When one says nothing one

means nothing. Of mechanics their knowledge was primitive. They knew the lever and the wheel and the pulley. But in all Europe, outside of Spain, there wasn't a man who could explain the principle upon which these devices worked. Not a man. Worldly wisdom was despised as something that might get between one and one's God. Ignorance, and its son Brutality ruled the human brain.

9

Then came the crusades—those monstrous nightmares that troubled the religious dreaming of a childish people. They were frightful, but they were cleansing. They served a purpose, though not the one for which they were intended. They curbed superstition, they broke down intolerance, they lessened the dread of religious authority, and they stirred vague but insistent inquiries into the why of things. In a word, they ended the century-long sleep, and the crusaders returned bitter and disillusioned—and awake.

The minds of men were ready, or almost ready, for the truth. And the truth-tellers were at hand.

*Chapter Ten*

# ROGER BACON

EUROPE was waking, and the end of her troubled slumber brought in scholasticism. This was better than nothing but only a little better. It was empty of originality, of research. It was merely a blind reverence for things dead. It was this movement that made Aristotle infallible and raised Galen to the height of a god. To question either of these ancients was equivalent to a sin against the Holy Ghost. There was no such thing as experimentation. Aristotle had solved all problems in metaphysics and natural history. Galen had told the world everything that could be known about the human body and the use of medicines. To know the writings of these two men was to be educated.

It seems amazing to us that anyone could be accepted with such blind faith. Today when a scientist makes a statement, thousands of others make experiments to check his conclusions. But the average child accepts, undoubtingly, whatever it is told—whether it has to do with fairies or Santa Claus or God. The men of Europe, in the twelfth century, were children with the minds of children and the thoughtless emotional reactions of children.

But just as here and there a bright boy of ten will raise objections and ask to have things proved to him, so now and then a man arose in Europe who refused to be blinded by faith and dared to ask why. Such a man—and more—was Roger Bacon.

2

He was born in 1214 at Ilchester in Somerset. A glance at your history book, under Henry III, will show you the kind of England into which Bacon was born. His people were well to do, and as a result Roger went up to Oxford where he took orders in 1233. He was a bright boy, and even at nineteen his ability was recognized. From Oxford he went to Paris and at the university there won the degree of doctor of theology.

While in Paris he fell under the spell of the Arabic writers. He was particularly impressed with Alhazen and Avicenna, and doubtless the work of these great infidels largely influenced his life. From the first, of course, he was destined for the church but this did not dampen his interest in science, which held strong even after he became a Franciscan.

About 1250, the strangest monk that ever lived returned to England and lectured at Oxford. His lectures were not on religious subjects. They dealt with science and with education. He was tolerant of everything except pose and sham. When he talked of learning he meant exactly what we mean today—a deep probing for the Truth. To the scholastics that wasn't a bit what learning meant. It wasn't what learning meant to Alexander of Hales, who was looked upon as the world's greatest educator because he had written a book with questions and answers, telling all that anyone could ever want to know. All a student had to do was commit this book to memory.

Against this man Bacon fired his hottest shots. He said his system of education was absurd and that Hales himself had not the smatterings of an education. He said he was a hollow shell as far as knowledge was concerned, and damned him and his kind as imposters,

3

Naturally this, in connection with his refusal to bow to ancient authority, was enough to ruin him. Promptly, Bonaventura, general of the Franciscans, ordered Bacon to stop his heretical lecturing and go to Paris. Friends pointed out to Bacon that if he obeyed he would be putting his head into the lion's jaws. In England he was safe. In Paris God knew what would happen to him.

Bacon was a simple and a trusting soul and more than that he was a conscientious man. His vows made it necessary for him to obey.

He went to Paris. And for ten years he was held a prisoner. He was not permitted to have books or instruments or writing material. His associates were brother monks who were not in sympathy with his notions and who made no effort to lighten his burdens. For ten years he was subjected to the severest discipline of the order and shut off from all contact with cultivated men.

However, one imagines his mind must have been constantly at work.

In 1265 Guy de Foulques, whom Bacon had known in England, became Clement IV and head of the church. Almost at once Clement ordered Bacon to write him a book on the sciences. Bacon went at this job with whole-hearted fervor. Books were still denied him, but all that he needed was in that head of his covered with a monk's hood.

In eighteen months he wrote the pope three volumes. They constituted a virtual encyclopedia of all science. They were not exhaustive, for they were meant to be enlarged upon later. But in a manner somewhat more elaborate than an outline, they embraced practi-

cally all the scientific knowledge of the day. It was as mighty a task as any man ever performed unaided in the history of the world. It proved that his reading had been wide, and his memory faultless.

4

To Bacon's age, and to the men who followed him, the Opus Majus, one of the three treatises written for Clement, was priceless. Here, for the first time since Archimedes, the true method for scientific research was clearly given.

Bacon's rules were: Accept nothing on hearsay. Accept nothing that results from inductive reasoning. Prove everything. There is only one guide to truth and that is experiment backed by deduction.

This was a new voice in the modern world. We who are the heirs and beneficiaries of scientific research cannot realize how startling these words were to the thirteenth century students who were steeped in religious dogma, lost in a maze of senseless quarreling over silly questions. Every one of them was egocentric. At no time in the history of the world were men so self-centered, so puffed up with a schoolboy egotism. This was a by-product of their religion. Were they not directly God's charges? They were of such vast importance that the Infinite Creator of the universe gave them His special and individual attention. In their minds and in their souls He had planted all knowledge. One had only to shut one's eyes and dig.

5

Here suddenly was a man, religious, devout, honest, who said that nothing can be learned that way. At best, by this blind method, you dig a pit for your soul and fall into it. He proved that he knew what he was talk-

ing about by analyzing some of the mysteries of nature and showing how easily the truth could be found by experiments. He took, for instance, the rainbow. Legends had been woven around this phenomenon. It was a beautiful mystery, a symbol, a warning, or a benediction. It could not be understood because it was supernatural—the tracing of God's fingers across the sky.

Bacon proceeded to show, so clearly that even the stupids of that time could understand him, that the bow was caused by rays of sunlight passing through rain-drops. It was simple. It was almost childish, but before him no one had thought to experiment with the bow of heaven. No one had thought that the colors in the dewdrops and the ocean's spray were identical with those in the rainbow.

Light seemed to fascinate this monk, condemned for so many years to the gloomy walls of a monastery, and he spent much of his time experimenting with lenses. Did he make a telescope? Did he make a microscope? No one knows. At any rate he understood and wrote of the principle of adjusting lenses so as to make distant objects appear near.

Why then did the world have to wait three hundred years for Galileo and the telescope? Because the church banned Bacon's writings. It is hard now to see why this was done. How could the church suffer through a probing of Nature's secrets?

6

Bacon's reach vastly exceeded his grasp, for his mind bridged a chasm of seven centuries and told him of marvels that only recently have come to pass. He foretold of ships driven by mechanical means and of horseless carriages and of airplanes. And this was not simply

a shot in the dark. Bacon knew something about a steam-engine and probably built one in his laboratory. What other monsters he constructed no one knows. However, he built enough to set the fools cackling and swearing he dealt in black magic.

All the books will tell you Bacon was an alchemist and believed in the philosopher's stone. He himself says of alchemy: "The problem here is not merely to transmute the baser into the more precious metals, but to promote gold to its highest degree of perfection." Note that he hangs an honest scientific problem, the purification of gold, onto the old, old problem, which, though he did not go to the length of denying it, must have seemed to him rather silly.

Indeed, when Bacon tackles one of the current superstitions he handles it gently—exactly as many agnostics do today when touching on religion. Some mild concession seems due to public opinion. So when this monk wrote of prolonging life he says, wisely enough:

"As yet we have nothing to rely on but ordinary rules of health. These are observed by but few, and usually not till the close of life, when it is too late. If suitable regimen were observed by all, no doubt life would be much prolonged."

This is modern enough and scientifically sound, but he went on to give a prescription that could only have been tossed out in a spirit of sardonic mirth. He writes: "A combination of gold, pearl, flower of sea-dew, spermaceti, aloes, bone of stag's heart, flesh of Tyrian snake and of Ethiopian dragon, properly prepared in due proportions, might promote longevity to an extent hitherto undreamed of."

You may if you like think Roger Bacon was perfectly serious when he wrote that; but it seems more probable that he was ridiculing his credulous foes.

All his life he was black magic to his neighbors. They hadn't the least idea what went on in that devil's smithy of his—but they believed the worst. His engine, his lenses, his eternal pottering with strange forms of life and strange elements were enough to send him to the stake. Giordano Bruno, three hundred years later, burned for less than that. So it is not surprising that the wise friar went as far as he could to countenance the time's popular superstitions. But even this could not save him.

7

Nicholas III lacked the courage and the learning of Clement IV. When Bacon's works were called to his attention he found them full of the most frightful heresy, and promptly condemned them. Once more the scientist was ordered to surrender himself to the Franciscans. He had seen this attack coming and had prepared a defense, in "De Nullitate Magiae." After all his defense could not help him much, for his enemies would never admit the wisdom of his words when he wrote:

"Because these things are beyond your comprehension, you call them the works of the devil; your theologians and canonists abhor them as the productions of magic, regarding them as unworthy of a Christian."

Naturally, talk of that sort wouldn't get him far with people who were already determined on silencing and destroying him. In 1278 he was thrown into prison, escaping with his life only because of powerful friends.

Imagine this man, already old, the greatest thinker then living, and the most learned, shut up alone and deprived of all means of carrying on his studies and limited to intercourse only with inferior minds, which were fired with hatred. This treatment he endured for

fourteen years, until, after he was broken in health and spirit, his friends secured his release.

But his work was done. He lingered for about two years and then sank into the sickness that proved fatal.

One feels that Bacon, realizing that twenty-four years of his life had been spent in prison, should have felt satisfied with the much he did while at liberty. Not so; for he says:

"It is on account of the ignorance of those with whom I have had to deal that I have not been able to accomplish more."

Dreams! And then at the very last, bitterness and disillusion, so that on his death-bed he said:

"I repent me now that I have given myself so much trouble for the love of science."

*Chapter Eleven*

# COSTER AND GUTENBERG

BUT this new fifteenth century is, indeed, a great period. There was a stirring in men's breasts—a reaching-out to gather in curious knowledge. Monks and scriveners filled the world with the scratching of their quill pens, feverishly copying musty philosophy, soul-strangling theology. And of the "making of many books there was no end."

But monks and clerks, working in dark cells, interrupting their labors to praise God, turn books out slowly. And when finished they are great volumes, each book an armful; costly, hard on the eyes, necessarily limited in output and circulation. Is there not for this divinely stirred animal, man, some readier way of manufacturing books?

2

Even now, and for a long time past, China has known a way, adopted later by aping Japan. Cut your characters on separate pieces of wood; there you have something enduring, that can be used over and over—multiplying by one operation the number of books a workman can produce.

But China, grown old before Europe took to a breechclout, is far away, little known and much hated and feared. Can any good thing come out of that rat-eating country? But Europe listens to the scratching of those quill pens and asks: "Is there no better way than

this?" Better? Who knows? Certainly there is a different and a rapider way.

Haarlem town, in North Holland, sprawls contented among its canals. Stolid and respectable burghers move along its streets. Little Dutch children, likely to grow web-footed from paddling in its waters, laugh into Holland's gay air. No thought in the mind of Haarlem that five centuries later savants will strive to get at the truth of a strange little incident taking place right now before the eyes of the Haarlemites.

Lourens Janszoon Coster was an innkeeper—and a man with a head on his shoulders. A kindly man, full of cheer, and well liked by all children. This last fact is important. He and these children, his own or another's, went for a picnic, finding their way through the gates of the town into the neighboring woods. There, idly, for the pleasure of his little ones, Lourens cuts letters in bits of wood, and then finding paper in his pockets, he prints a couple of words for each child—using for ink one knows not what.

The children are delighted, as your youngster is today with his name set on a slug from a linotype machine. But Coster, being a man with a head on his shoulders, strolled back to town thoughtfully.

"Is there not," he asked himself, "the germ of an idea in this trick I have made for these children? Better turn it over in your head, Lourens, and sleep on it."

3

"Movable type? Why not? Set up your page, print it; take your type and set another page. There is no end to this thing," ran Coster's thoughts. "You printers who, trying to beat the scratching monks at their own trade, have laboriously carved on a block of wood a page of manuscript, are you not wasting time? Your

copies once printed, your block of wood is useless, fit only for the fire. A slow job, this carving, and all to be done over again for each page of your book. Now with my movable type . . .

"To get these letters even and readable in wood and small enough to be usable, will not that prove a task too great? It seems likely. But there are other things. Metal, for instance, which can be heated and poured into molds. Could we not get our letter set on the end of a punch of steel, and drive this into a bit of soft metal, which could then be used in casting our type? One punch for each letter, and thousands of letters from each mold!"

This innkeeper, with a head on his shoulders, pondered the problem, set about making an experiment, actually produced type, much in the way indicated. With his own hands, most likely, he designed the letter on his steel punch; and with his own hands, certainly, he cast the type and set it into words, and the words into a page from which he hammered out an impression on his paper. A slow process slowly repeated for each page of his book.

Finished at last, and there it stood—the first printed book in the long history of Europe.

What was the date? Some say 1420 or 1428, others 1440, or 1446. At any rate appear it did, the first book printed from movable type and certainly given to the world before the middle of the fifteenth century.

4

What of Coster, this innkeeper who turned printer? Faint hints appear in old Haarlem's records. Confusing, these, for there was more than one of that name. For long his identity was lost behind that of an imposter, Laurens Janszoon—never surnamed Coster.

From behind this false prophet, the real Coster finally appears.

Looming through the murk of five centuries, he stands silently protesting that it was he, and none other, who first cast separate type and arranged them into a printed book. Let him have his way. At least he appears as a symbol of man's hatred of scratching pens in monks' cells and man's insistence upon making his books in a cheaper, faster fashion.

5

From German Mainz-on-the-Rhine come cries of "imposter and fraud." Never shall the honor of freeing this giant go to Haarlem. To Mainz it belongs, to our own Johann Gutenberg. To prove it was right, Mainz, in 1900, staged a great celebration in honor of Gutenberg, inventor of printing.

Did Mainz steal the idea from Haarlem or was it the other way round? Was there no such person as Lourens Janszoon Coster or was Gutenberg never a printer? Lovers of fine points may fight it out, and much good may their decision do Mainz and Haarlem —or Coster and Gutenberg!

6

Certain it is that printing was improved at Mainz. That Gutenberg had a hand in this improvement seems also certain. That he lived, and strutted through Mainz and Strassburg no one denies; not a shadowy figure of a man but a reality. At times he was prosperous, buying large quantities of wine—and drinking it. A good fellow, one who made friends easily—and lost them; hotheaded, quick to fight for his own; a fine persuasive talker, full of ideas and large prospects; but a secretive man.

Did he get this printing idea in 1436? Out of Haarlem or his own head? Or did he not get it until much later? He worked on the problem for years at Strassburg, at Mainz, say his friends. Otherwise what was he doing? Why was he borrowing all those gilders? For help on his invention? There is no mention of invention, and those who order large quantities of wine, and drink it, are apt at some time to turn borrowers.

And the gilders were not repaid. No, and the interest was not paid. Friends fall away under such circumstances. They fell away from Gutenberg, went to law with him, got him to pledge his tools for the debts, let him drift, him and his dreams, into poverty, into the mists of time, so that one knows not the date of his death.

The first Mainz printer of books thus disappears, passes out, and his name no longer is found in the town records of Mainz.

## 7

But printing is born and movable metal type has come into existence and is to endure forever—or for as long as civilization can stand it. Printing spread rapidly, and before the beginning of the sixteenth century almost every large town had its busy printing-press grinding out books, and literacy was abroad in the world. The art of penmanship, fallen on hard days, was to fall on ever harder, until pens were mere curiosities, remnants of a dead age.

William Caxton, apprenticed to a silk merchant, and sent to Bruges in the way of business, found printing for England. He left the silk trade in 1473, and set about learning all there was to learn of type and presses. Full of these facts, and with the experience of two books published by him at Bruges, he returned to

England in 1476 and set up a printing-press at Westminster at the sign of the Red Pale. There, for fifteen years, he busied himself writing and printing.

Being a reactionary, Caxton bitterly complained of the changes taking place in the English language. In an effort to head off this deplorable tendency he published Chaucer's Canterbury Tales. There are many who, once caught by the swing of Chaucer's words, deeply wish Caxton had won that fight.

Having done his work as an evangel of a free press, Caxton was gathered to his fathers in 1491.

8

Printing crept into Scotland about 1507 and into Irish Dublin a little later. It crossed the ocean fifty years after Columbus's first voyage, and a press was set up in Mexico in 1544. It came into United States territory hard on the heels of the Pilgrims, and a printer was busy at Cambridge, Massachusetts, in 1638. Writing and publishing, however, was not to be confined, and it swept on through all the colonies, crossed the Pacific, girdled the globe.

If all the books that have been printed since that fateful day when Lourens Janszoon Coster cut letters in wood to amuse children were laid end to end—But what's the use? Of the making of many books there is indeed no end.

The age of paper arrived and threatens now to continue—pointing toward no certain Utopia. Coster or another freed the goose, and the cackling of that emancipated bird has for five centuries filled the ears of men and has been found musical by the many, discordant only to the few.

*Chapter Twelve*

## COPERNICUS

BACON's genius died with him, and the bulk of his work was lost. He was a light in the midst of Europe's darkness, and the darkness extinguished the light. He left the world as he found it. It was an age of fanatics, and power was in their hands. For another two hundred years no giant stepped across the plains of Europe.

And then came Copernicus.

Nicolaus Copernicus, born in 1473, was, like Bacon, a churchman. That is not surprising. In that age there were only two trades open to ambitious young men: the army and the church. Copernicus was too wise to be a soldier.

Thorn, on the Vistula, was his birthplace and he was a German; some think, a Prussian. If so, he was far from the popular idea of a Prussian. He was sickly, studious, kind-hearted, religious, and modest. His desire for knowledge was insatiable. As a result he studied medicine at Cracow, then went to the universities of Vienna, Bologna, Padua, Ferrara, and Rome. In each of these schools he pursued mathematics like a zealot and devoured every book on astronomy that he could find.

When he was twenty-four years old he went to Frauenburg as canon and for most of his life remained there.

2

No superstition fettered this priest. He practiced medicine gratuitously and did not believe disease came from God and could be most easily cured by praying at a shrine or adoring a relic. He dared to look Nature in the face and he did not let his devotion persuade him the Bible was a book on science. This means that here was another man born to use his brains.

Everybody in that day, popes, emperors, and the common of commonest, believed the world stood still. They didn't all think it was flat, though most of them did; but they all said the earth was the center of the universe, around which everything else revolved. Whoever denied this was a heretic, and the quicker he was sent to hell the better. That was the fine heritage old Ptolemy gave to Europe.

Copernicus believed in hell as fiercely as the best of them. But he didn't expect a man would be damned simply for using his eyes and his brain. If he had any doubts, he put them aside and was willing to run the chance.

3

Some of the Greeks, you remember, Pythagoras for instance, taught that the sun stood still and the earth moved around it. Copernicus came across this idea, and it seemed reasonable to him. The more he thought, the more likely it seemed that the earth did the moving. He began making calculations and he found that on this theory things fitted somewhat better than they did on Ptolemy's plan. He had to use epicycles to make the changes of the planets come right, but that was due to his belief that everything moved in a circle. This per-

fection of the circle idea he also got from the Greeks—chiefly from Aristotle.

Copernicus did not at once make his data public. Two things stopped him: he wasn't absolutely certain he was right; he was afraid of the Bible.

No one alive at that time could forget that Joshua had commanded the sun to stand still—and it had so stood. But Copernicus did not believe the Bible was a textbook in science. It was a religious revelation, it was inspired, and it presented a fine code of morals. These things he believed, just as he believed in a personal God.

He realized that the vast majority of people believed the Bible from cover to cover, doubted the existence of any knowledge outside of it, and certainly would not accept anything that was opposed to a biblical statement. They were tolerant as long as one agreed with them. Copernicus didn't want to get into trouble; and getting into trouble was one of the easiest things in the world for one who did a little thinking on his own. He worked out his theory, with mathematical proof, and then put the manuscript away and forgot it. He went about taking care of the sick and tending to his church duties—and thinking.

4

He didn't care a rap about fame. He wanted to know the truth, and he was willing to pass this truth on when found. So when George Joachim came asking, he told the young man all he had discovered and showed him his book. Joachim was a professor of mathematics at the Lutheran University of Wittenberg, and he also was a searcher after truth. Not that the Lutherans ever doubted the scientific wisdom of the Bible. Luther, who had read widely, thought much and defied

all the devils in Worms, would have nothing to do with the new idea, and called Copernicus a fool, which is an easy word to say in any language, including the German.

Joachim didn't agree with the head of his church, and he gobbled up the Copernican theory instantly. More than that he insisted upon the publication of Copernicus's life work, "The Revolution of the Heavenly Bodies." Copernicus yielded. He was growing old, and his health was bad. There wasn't much that the church fathers could do to him. Death would step in directly and end it all. Even so he took no unnecessary chances. He wrote a preface addressed to Pope Paul III which was of a highly conciliatory and apologetic tone.

"I can easily conceive, most Holy Father," he wrote, "that, as soon as people learn that in this book I ascribe certain motions to the earth, they will cry out at once that I and my theory should be rejected. I am not so much in love with my conclusions as not to weigh what others will think about them. . . . Therefore, when I considered this carefully, the contempt which I had to fear because of the novelty and apparent absurdity of my viewpoint nearly induced me to abandon the work I had begun."

Near the end of this strange preface, Copernicus sounded a freer and more defiant note:

"If perchance there shall be idle talkers who, though they are ignorant of all mathematical science, nevertheless assume the right to pass judgment in these things, and if they should dare to criticize and attack this theory of mine because of some passage of Scripture which they have falsely distorted for their own purpose, I care not at all; I will even despise their judgment as foolish."

So prefaced, the epoch-making book was given to the world. You mustn't imagine that it made an instant hit and became a best-seller. No, indeed! It was scorned and rejected of men, and long after Copernicus was dead it was damned by the church. Tycho Brahe, of whom you will hear more, and Francis Bacon refused to accept it. More people laughed at it, than believed it. To the average man it seemed downright idiotic and rank heresy. Copernicus, however, was spared the gibes and the praise.

5

Imagine, for a moment, this old doctor-priest, going about his simple duties in Frauenburg. He has grown old in the service of God and of man. He has thought much, worked hard, and is nearly through. When Joachim insisted upon publishing the book, doubtless the old man was thrilled. In all the years of his life, few things out of the ordinary had happened to him. He had lived close to the pains of men. A doctor and a priest see men at their saddest. It is quite likely that for thirty years he had borne on his shoulders the burdens of half the people of Frauenburg.

Never had Copernicus thought of himself as a great man. Aristotle was alive with conceit, and Roger Bacon sensed his own genius. But not for an instant did Copernicus dream that his name would last as long as the world stands. His book was to be published, and he was thrilled and he was scared and he was a little saddened. He knew what intolerance can do to a man who dares to walk alone.

Probably he whispered to a crony here and there that big things for him were going on and, God help him, he didn't know what would happen when the cardinals got hold of his book.

He was in a fever of excitement, and fever sent him to bed. He lay there waiting, waiting—and the book did not come. And death did not come. He wanted his book, and the process of making it was so slow. He grew weaker, but he still hoped. Hope died. The spirit was draining out of him. And then—

Post-haste, a copy of the book was rushed to the dying man's bedside. It was put into his hands. His fingers caressed what his eyes could no longer see. In an hour Copernicus was dead.

6

For more than a thousand years, Ptolemy had reigned. This priest and doctor, lying forever silent, with a freshly printed book clasped in his hands, had dethroned the pretender and joined that small group of rebels that has greatly influenced the world's history.

Francis Bacon, known to science as the man who was always wrong, wrote fifty years after Copernicus's death:

"The many strange things which he assumes, are proceedings which mark a man who thinks nothing of introducing fictions of any kind into nature, providing his calculations turn out well."

Bacon was one of the "idle talkers ignorant of mathematics" at whom Copernicus had thrown his words of scorn. A truer estimate of the great astronomer was made by E. F. C. Morton who wrote:

"The dim Titanic figure of the old monk seems to rear itself out of the dull flats around it, pierces with its head the mists that overshadow them and catches the first gleam of the rising sun."

Simple, courageous, patient, Copernicus dug for the truth and recognized it when it came to light. He had

not the flaming genius of Galileo nor the mathematical power of Kepler, but he was brave when that was the only virtue worth while; and he was honest when all around him were corrupt. He was born to be a sturdy iconoclast and with hard blows he labored to destroy Ptolemy and drive one more error out of the world.

## *Chapter Thirteen*

# PARACELSUS

BASEL and the University of Basel were living the staid and respectable lives of the self-satisfied. The citizens were God-fearing and church-fearing folk. The professors were old fogies—who accepted what the books set down as fact, and among these facts were the thousand and one errors immortalized by Aristotle and Galen. Were they questioned? Were they checked up? On the contrary, they were passed on as absolute truths.

And all this passing was done in Latin. Nobody knew why, but it had always been that way, and therefore must be right. The mysteries of science and philosophy were too sacred to be discussed in vulgar German.

2

It is summer in Basel in the year 1526. Something of a ripple has run through the learned circles of the town. A famous doctor is coming to see them. They chatter among themselves as to what kind of man this Paracelsus will prove to be. Reports of his cures have spread before him. He is a miracle-worker. No mere doctor could do the things he does. They decide he is either in the service of the devil or endowed by his Creator with the great gift of faith.

While they gossip, Paracelsus arrives.

At first sight he is rather overwhelming. A velvet

cap is cocked jauntily on the side of his large head. His long hair frames a face alive with animation. His eyes are dark and glowing and around them run laughing wrinkles. He is heavy, with broad shoulders and he sets his feet down firmly, as is the habit of one who knows where he is going and why. With sword clanking at his side and his cloak blown back by the wind, he looks more like a swashbuckling roisterer than a great physician. He is a good deal of each.

The professors and the big-wigs of the town stare, but when Paracelsus speaks to them, they lose their reserve. There is the magic instrument of the man—his voice. It is full of warmth and music and a fine, persuasive friendliness. With it he makes friends and draws the crowd after him; with it, he bewitches the red-cheeked German girls and talks himself into and out of many a scrape.

It is nothing to wonder at then that he has no trouble talking himself into the job of town physician. Once in office, Paracelsus is busy. Only thirty-six, he is still young enough to have a fine zeal for his task. And the authorities help him. Never lived a man who could make friends so quickly. Or so completely and swiftly lose them. It is only a matter of a few days and Paracelsus is all the rage.

That's how it happens that he is asked to lecture at the university. Those lectures are to be a great thing for medicine and the mental growth of Europe. But they are to ruin Paracelsus.

3

On the door of the university, Paracelsus posted a notice of his lectures. This was not a modest notice. He announced that he was the great and only Auriolus Theophrastus Bombastus von Hohenheim, most learned

of physicians. He would not, he said, lecture from the books of Galen and Avicenna, the Arab. He would lecture from the Book of Nature, whose pages he had trod and whose secrets he had won.

He capitalized the effrontery of this notice, and his lecture room was crowded. Then, to the amazement of everyone, Paracelsus spoke in German! It was unbelievable. It was sacrilege! The students were delighted, but the professors were shocked and that was only part of the shock they got.

Paracelsus, whose egotism was expressed in this self-assumed name, which meant he was as great as Celsus, attacked the doctors and the sour-faced professors. He said he hated and despised men who spent their lives in the grip of a dead hand. None of that for him. Books were dead things. Nature was alive, fascinating and truthful. Books were packed with lies and errors. Those who read books were ignorant and self-satisfied. As for himself he read no books, but he knew more than all the other doctors put together. Then he fired facts at them. He told them things about medicine and chemistry they had never dreamed of. The fury of his conviction that he was right drove his words home. He not only held his classes, he flamed out as the great man of the age.

4

Where did Paracelsus get the data he tossed to his students and hurled at the heads of the doctors? From Nature, from an inheritance that gave him that kind of mind.

His father was the bastard son of a nobleman, and trained as a physician. His mother was a nurse, superintendent of the hospital at Einsiedeln. When she met and married William Bombastus von Hohenheim, she

gave up her nursing and settled down to the task of being a doctor's wife.

So fathered and so mothered, Paracelsus was born in 1490. As a mere child he studied medicine with his father, who obviously belonged to the old school and had none of his son's fierce individuality. At sixteen he entered the University of Basel where, twenty years later, he was to lecture.

Even at sixteen, the school routine sickened him. He left the place in disgust and went to Sponheim where he studied chemistry with J. Trithemius, who at that time was the last word in this science. It was a science only by courtesy. It was still alchemy. The philosopher's stone was the object of all work in the laboratory.

What Paracelsus thought of all this, nobody knows, but he learned something of chemistry and used it all his life.

This inquiring boy did not find at Sponheim, any more than at Basel, that for which he craved. He wanted to tear Nature apart and see what made the wheels go round. He wanted life in the raw. Life was about as raw in the mines at Tyrol as it was anywhere in the accessible world. These mines were owned by the rich Fuggers, and through the help of this powerful family, Paracelsus was able to visit them.

There he found what he sought. He saw the effort with which Nature gave up her gold and silver. He learned a lesson from the struggle necessary to refine those metals. He saw men, beaten, exhausted, dying. He saw them crushed by accidents. He studied Nature's way of repairing these ravages. In short, he learned in Tyrol to be a physician.

It was there he resolved to read no more books but to go direct to the crude material for all his knowl-

edge. This determination sent him on far wanderings. He said, "One must read the book of Nature and walk over her leaves." He walked. For years he wandered across the face of Europe. He may even, as he claimed, have penetrated the East and have sat at the feet of wisdom in Syria, in India.

It was during this period that he won the title of "the ignorant vagabond." Probably the vagabond part fitted. It is doubtful if he had any money save the little he could earn as an itinerant doctor. At best, small pickings. And he couldn't get along without cash as easily as some. He liked a good time. He liked his liquor. He liked to parade in fancy clothes with an expensive sword on his hip.

5

Thus he swaggered through Europe. But no matter what he did with his boon companions, he was, for the most part, a poet and a student. Wherever he went, he gathered knowledge. His memory was perfect. If he did not classify his facts, he still held them in mind ready for instant use. He studied the diseases to which men were subject in the various countries. He analyzed the local treatments—and improved on them. He said truly: "To know my own people, I must know all people." This was the task he set himself, and he wandered, seeing his course "as birds their trackless way."

He bluffed. Fooling others he fooled himself. The time came when he more than half believed his often repeated claim to all the wisdom in the world. But if he deluded himself along that line, he was rigidly honest about other things. He had a fine idealism toward his profession. He saw the doctor as a man who braved all for truth and who hesitated before no sacrifice in his service of humanity.

This profession, which he wanted to honor and elevate, had been fouled and degraded by ignorance and superstition. So he hated ignorance and superstition. He hated the men whose minds were locked and whose aims were low. The fire of a crusader was in him. He sought facts and truths with which to attack his enemies, with which to wage and win his fight for reformation.

6

This was the man who set Basel roaring with his lectures in German, his tirades against the doctors.

But, if Basel shouted as Paracelsus hurled his anathemas, it was shocked into silence by one of his most astounding and dramatic gestures:

The students, holding a celebration, built a bonfire, and as they danced and sang around it, through the front door of the university came Paracelsus. His cap was cocked at as jaunty an angle as ever, but on his face flamed the light of a fanatic. In his hands, raised above his head for all to see, he held two books. One was by the deified Galen and the other by the supreme Avicenna.

"Behold," cried Paracelsus, "the death of the old and the birth of the new." With these words he flung the two sacred books into the fire. "So let their errors and false teachings perish," he said. "What of truth there was in them cannot be destroyed."

In this act blazed the spirit of the man. He was ruthless: he was a truth-seeker.

This insult to the gods of medicine stirred Basel with hatred of the heretic. Even his disciples were shocked. Those who had disliked him, now loathed him. Those who had feared him took courage from the popular attitude and attacked him. He was de-

nounced as a quack. His character was spattered with mud. He was challenged to prove that he had a degree as a doctor. His methods, his claims, his vanity were ridiculed. He was riddled with lies and slander. His popularity vanished overnight, and Paracelsus stood, a lonely figure, fighting a city of enemies.

Yet he continued telling the doctors what he thought of them, continued his work as health officer, and ministered to the sick. He wouldn't be stopped. The odds were all against him, but he fought on. He was defeated, but he had shaken the dry bones of medicine. He had started a fire and he fanned it into a great blaze.

## 7

Paracelsus was hated, but his cures spoke for his skill. He was a braggart and a nuisance, but he knew his business. When a case became desperate, and the old-time doctors failed, this "quack" was called in.

That's what happened when Canon Cornelius von Lichtenfels thought he was dying. The doctors said so. The Canon knew that only one man could save him —and he sent for Paracelsus.

Cornelius loathed the upstart, but he wanted to live. Paracelsus looked the Canon over. He said he could cure him. But he knew he was dealing with an enemy, so before anything else he talked about a fee. He named a stiff price. "To be paid if I cure you," he said. The Canon eagerly agreed. He was buying his life.

Paracelsus cured him.

Then he tried to collect his money. The Canon laughed at him. The fee, he said, was exorbitant, and he could prove it in a court of law. He offered Paracelsus part of the amount demanded. This was refused. The vagabond had his price—and a strict sense of

honor. He had his professional pride, and the Canon had insulted it.

He appealed to the courts. By nature and habit, judges are reactionary. Paracelsus was a firebrand. He was opposed to set form and order. Here was a chance to put him in his place. The judges sided with the Canon, and Paracelsus's claim was thrown out.

Paracelsus had been badly treated and he knew it. He voiced his anger in bitter words. He told everyone exactly what he thought of the Canon, of the judges, of the whole system. His language was strong but tactless. It did him no good and it stirred up and united his enemies.

8

Paracelsus had been in Basel less than two years. He had won fame and popularity and had lost them. There were few left to defend or help him.

The Canon, the doctors, the professors, the judges were all against him. They talked things over and decided to get rid of the trouble-maker. Most of them wanted simply to run him out of town; a few desired his death. These few laid their plans. Paracelsus, in his wild way, had insulted them, their ancestors, and descendants. It was a crude age, and justice was largely a private matter. To mutilate or kill the doctor would restore self-respect and peace.

A friend discovered the plot and warned Paracelsus, when the vengeance-fired clique was ready to strike. The doctor was no coward, but he could not fight a dozen. He fled. He had no time to take with him any of his belongings. Hastily and at night, he left Basel, never to return. His few friends, his books, his instruments, even his clothing were lost to him. Alone and

destitute he set out on long years of wandering. Never again, or only briefly at the very end, did he have a home. He could not shake off the blows Basel continued to deal him.

9

Still he refused to surrender. He went on, sounding his note of defiance, rattling skeletons, damning the past and pointing to the dawn. Colmar, Nuremberg, Appenzell heard his voice and listened, until the storm from Basel blew the medical prophet into new fields. Always Basel hounded him. He could find no permanent abode, scandal being hot on his heels. Seldom could he stay more than a few months in a city—never so long as a year.

He lived in want and poverty. A few cases, a few paltry fees, then on before the pack he raced. No chance to experiment, to equip a laboratory, to write at leisure. He was a homeless wanderer. So he saw Zurich, Pfäffers, Middleheim, Meran, Villach, Augsburg. A stranger in each, a solitary intruder, who blustered and caroused and passed on. A sadder road-stained figure of genius, the world has not seen.

Hard travel and hard living aged this evangel of a new age in science. Neither time nor turmoil could dim his spirit. Defeat and poverty could not silence him. He had a truth to tell and he shouted it to the world.

He was thirty-nine when he escaped from Basel. He was past fifty when a refuge was at last offered him. For more than ten years he went up and down the ways of Europe, scoffed at and mocked. For more than ten years, bitterness ate at his heart. He knew his worth and genius; he knew the power of his message. None or few would listen to, or believe in, him.

10

In 1541, Archbishop Ernst of Salsburg beckoned the wanderer home. How gladly Paracelsus went! Here was the chance he had for long demanded. A laboratory, leisure, freedom from worry, peace. Now he could set down on paper his thoughts. He could test his theories, he could do all the thousand things he had planned and dreamed. Do them all—if only there were time!

But time was short. Salsburg knew him for only a few months. What spark fired the last great scene in this bewildered giant's life? It may have come from Basel—some enemy spreading old scandal in Salsburg, where Paracelsus had a right to consider himself safe. He had come to rest and he was innocent and he had found a friend. Then the old lies bobbed up. It was rather more than flesh could bear.

Paracelsus flamed anew, with his fine new cloak waving in the wind, his old sword clanking at his side, his cap still jauntily cocked, his great head now snow-covered, his face heavily lined, but his eyes still flashing defiance. Was he tracking a scandalmonger when he went to a public-house that fatal September 24 in 1541? Or did he go merely for a cheering drink and a word with pleasant acquaintances? Whatever his mission, Death shouldered past him as he entered that room.

It was over quickly. Some slighting word, some stirring of an ancient insult, and there came an upflare of the fierce temper that had forced him from Basel. But now Paracelsus was old and broken. The instant swift reaction that had saved him a thousand times faltered for half a second. There was the death-thrust, and the greatest doctor of the age was a heap of dust.

11

Or will you believe another version, a legend, of his death? Paracelsus out for a walk, seeking the country and the kindly face of Nature that he loved. On the edge of a precipice he paused. The evening sun was in his face, and the heavy shadows were at his back. Below, far below, the waters passed over rocks and shining sand. The great man was at peace, anchored, safe. He was dreaming, not of the wasted years and the time spent in exile from his laboratory, but of the work ahead, of the hard problems to be solved.

He was dreaming of the cosmic forces. Of the universe of which he was a part and which was a perfect unity. Of the divinity that swayed him, that painted the flowers at his feet and the colors in the sky. His faith was great, and there was peace in his heart.

Behind him a movement, the catch of a breath. Shadows stealing out of the shadows. The head of the old warrior came up. His hand flew to sword-hilt, too late. There was a brief conflict, and Paracelsus went over the brink of the cliff, hurtling down against the rocks, crushed, silenced in this world forever.

History does not name the wretches who in publichouse or on the high places slaughtered this man.

But he, their victim, lives on, forever strong, forever a voice stirring the souls of men. He belongs to the small band of immortal rebels: Spinoza, Galileo, Harvey, Lister, Faraday.

12

Paracelsus was no creative genius. He was an iconoclast. He slew ghosts. He cut off the dead hand that for more than a thousand years had held medicine in

its grip. He dethroned the stars as active agents in human affairs. He raised Nature to her feet and crowned her with new dignity. He burned the little books of men and pointed the way to the fine tablets of experiment. He was supreme as a pioneer blazing trails. He was a tireless, ceaseless, undismayed seeker after the truth.

*Chapter Fourteen*

# TYCHO BRAHE

NO people bound down by superstition can grow. Ignorance finds an answer and it's always wrong. This stops inquiry, and when you take out the "whys" you squeeze the brain dry. No people ever lived who could beat the Europeans of the Middle Ages at superstitious fancies. These myths and ignorances were all bound up with their religion. To tackle one was to tackle the other; that meant trouble, prison, and a flaming bunch of fagots with the heretic in the middle of the blaze.

It was safer and more comfortable to be superstitious.

The growth of Europe's brain ran parallel with the death of silly fears and beliefs. That's why astronomy came out of the Dark Ages, to give birth to the modern world. Astronomy was a fairly safe science. It was certainly better than trying to tell people something about their own bodies. Michael Servetus, Spanish anatomist, found that out—too late. The Inquisition got him, and he was burned alive in 1553. All he did was to try and knock out a few superstitions. That was enough.

Tycho Brahe didn't go in for medicine or physiology. With his temper, he'd have had a bad time if he had done so. It was a good thing for him and a good thing for the world that he stuck to stars.

2

Tycho was born in Scania, then a Danish province, in 1546, the oldest boy in a family of ten. His father, Otto Brahe, was a lawyer, held government jobs, and at last was put in charge of the castle of Helsingborg.

But Tycho's father did not rear him. That job was taken over by his uncle. Before Tycho was born Otto and his brother agreed that Otto's first boy should go to George, who was childless and wanted to adopt a son. When Tycho was born, Otto and his wife refused to give him up. This led to some bitterness between the brothers. George, however, let the question ride until, a year later, Otto's second boy was born. That was too much for the lonely man, and he promptly kidnaped Tycho. As they now had another baby, the parents apparently thought it was not worth while fighting with the rich brother, so they left Tycho in his care.

At thirteen, Tycho entered the University of Copenhagen. He was a wild, harum-scarum sort of boy, as might be expected of one reared by a doting uncle. With no interest in his school work, he took life as it came and let it go at that.

But when he was fourteen years old something happened that woke him up. On August 21, 1560, there was an eclipse of the sun, visible in Copenhagen. This phenomenon made a deep impression on the boy. It was not the wonder of the spectacle that struck his fancy—it was the fact that it had been foretold with absolute accuracy.

3

Tycho resolved then and there that he would learn enough about astronomy and mathematics to be able to make such predictions. He secured Ptolemy's astronomical works and began studying them. His getting

this notion of the heavens at that early age probably accounts for the tenacity with which he clung, all his life, to Ptolemy's views. At no time was he able to see any sense to the theory of the "mad Copernicus."

This scientific stuff enraged his uncle. He wanted his nephew to be a lawyer—and a decent member of society. In order to cure him of star gazing, he packed Tycho off to Leipzig in 1562. Along with him, George sent a tutor named Vedel, four years older than Tycho. It was Vedel's job to see that Tycho cut out the stars and stuck to rhetoric.

Vedel was a conscientious fellow and he did his best to earn his salary. But Tycho was too smart and too industrious for the tutor. When Vedel was safely tucked in bed, Tycho would crawl out and spend long hours watching the stars or studying mathematics. His energy was enormous. Nothing seemed to tire him, and a couple of hours sleep was all he needed.

At seventeen, Tycho began a serious study of the planets. He found that their positions differed widely from those set down in the books. This started him making observations with all the accuracy possible. Thus he was launched upon what proved to be his life work. Tycho had no telescope and only rude home-made instruments. In time he learned to make better tools, but he never had a chance to look at the heavens through a lens.

Tutor Vedel's espionage ended with the death of his uncle, when Tycho was nineteen. Thereafter, having inherited a fortune, he could do as he pleased—and he did.

4

From Leipzig he went to the University of Rostock and almost immediately jumped into an undesirable

fame. An eclipse of the moon was due, and Tycho made a public prophecy that this eclipse foretold the death of the sultan of Turkey. News of the sultan's death arrived and, briefly, Tycho was a hero and a man of destiny. But when word came that the sultan had died before the eclipse, the young prophet's fame was turned into notoriety and ridicule.

Tycho was no man to appreciate a joke on himself. He was easily enraged and he resented every gibe. It is quite likely that this false prophecy led to the only duel in which Tycho ever engaged. Anyway, he quarreled with a fellow student—some say over the question of which one knew the more mathematics.

Tycho and his enemy agreed to meet in the dead of night and fight it out with swords. There was no light furnished for the duel. It was pitch-dark, and the fighters found each other only by ear. The combat was waged fiercely for some time with no damage done. Then Tycho got his nose in the way of his opponent's sword. At that instant he lost the fight—and his nose. Honor was satisfied and Tycho was led to a doctor.

The Great Dane was not content to go through life without a nose. Not at all. He set about making himself one out of silver and gold. Some say copper alloy. You may be sure it was not copper. Nothing so common would suit the aristocratic Tycho. This manufactured nose he cemented in place, and his enemies said it looked better than the old one. Of course, occasionally it would drop off, but Tycho always stuck it back on again and went about his business undisturbed.

The surprising thing is that Tycho didn't fight oftener. He had a vile temper and a bitter tongue. Sooner or later he quarreled with almost everyone he came in contact with, but in time his friends learned not to take him too seriously, and so he escaped killing.

5

Always Tycho had what we call color. That is, he was a showman, theatrical. His hasty prophecy at Rostock proves that, as well as his duel in the dark. This theatrical trait led him to believe in astrology and alchemy. He loved, all his life, to startle people, to do the unexpected and bewildering thing.

It was this trait, probably, as much as anything, that led him into alchemy. At that time there was no such thing as chemistry—as chemistry is known today. Alchemy was not a science, though it posed as one and aped scientific methods. Tycho thought gold might be obtained through alchemic processes, and he tried to get it. But along with this quest he studied old prescriptions and concocted a few new ones of his own. One of his "patent medicines" became extremely popular, and no one could be considered quite healthy who hadn't taken it. Strange and unbelievable ingredients went into this stuff. But among all the junk there was a small amount of antimony, and to this the nostrum probably owed whatever value it had.

Brahe might have gone on and wasted his life stirring messes in his laboratory if the stars hadn't interfered. One evening in November, 1572, Tycho, looking up at the sky, was startled. He would not believe his eyes. He appealed to his coachman. The man confirmed Tycho's doubting judgment. What they saw was a brand-new star. Night after night it shone and constantly grew brighter. At last it rivaled Jupiter in brilliance. Then its light gradually faded and at last it disappeared. The phenomenon threw Brahe back to to his first love. It did more than that. He studied the star in all of its changes and finally wrote out carefully what he had seen. He wouldn't, at first, publish it, be-

cause printer's ink was beneath the dignity of a nobleman.

For the same reason he refused to lecture at the University of Copenhagen when asked to do so. However, he changed his mind about this when the king suggested that he'd like to have the lecture given.

6

Tycho had returned to Denmark to settle up his uncle's estate, but at that time he had no intention of staying there. He thought Prague or Basel would be better suited to his work. So he began getting ready to leave Denmark forever.

A queer change occurred in Tycho at just this time, and none of his biographers seems able to explain it. The aristocrat, who had been too proud to publish an article on a new star or lecture at a university, suddenly became a radical. He snubbed his high-toned friends and went about dealing out, with no charge, his medicines to the peasants and making friends with quite common people.

He did more than make friends: he fell in love with the daughter of a peasant. Tycho was an eccentric nobleman, but not even he ever dreamed this would happen to him. Apparently he never dreamed of falling in love at all. All the marriageable daughters of Copenhagen had been after him. But to Tycho they made no appeal. The peasant girl did.

All of his family and all of his friends said he was a fool—or came as near saying it as they dared to so quick-tempered a man. His relatives quarreled with him, but Brahe told them to mind their own business and then went ahead and married his peasant girl. And lived happily ever after. At least as far as his wife was concerned.

History hastn't revealed much about this wife, but she must have been a fine, healthy, level-headed woman. Being a wife to Tycho was no snap. He was fierce, proud, self-centered, and vastly ambitious. He could be tender, forgiving, considerate, but he was seldom in the mood for these white virtues. No matter; the peasant wife endured all, bore him many children, kept his home peaceful, and passed lightly over her husband's glaring faults.

7

Just as Tycho was ready to shake the mud of Denmark from his feet, Frederick II sent a hurry-up call to have his famous subject brought to the palace. That meeting led to great things for science.

Tycho was persuaded to stay in Denmark.

Frederick made big concessions to keep his stargazer. He gave him the Island of Huen in the sound, as the site for an observatory and set aside a sum about equal to $100,000 to be used for buildings and apparatus. A pension of about $2,000 was settled on Tycho along with the income from an estate in Norway.

Tycho, you see, had fallen upon fat days, for his despised science had won royal approval. Work was at once begun on the observatory, which was to be the largest and most elaborate in the world. The cornerstone was laid on August 8, 1576, and the observatory of Uraniborg (the Castle of the Heavens) rose rapidly. Here for twenty years Tycho Brahe made his observations and collected the data that, long afterwards, were published as the Rudolphine Tables.

8

This was the golden age in Tycho's life. He was doing the work he loved under conditions as nearly

ideal as he could imagine. Night after night he sat at his quadrant, making the most careful observations and painstakingly marking them down. He was, for the most part, correcting errors that had been part of the star tables for hundreds and hundreds of years. You must remember that Tycho's instruments, judged by modern standards, were crude to the point of foolishness. He had no telescope—he had only his two good eyes. Yet in spite of his handicaps, his observations are still the admiration of scientists.

It is hard to believe that Tycho, watching the stars swing around in an endless procession across the sky, did not sense the truth of the Copernican theory. But he didn't. He was a supremely vain man, and this vanity may have blinded him to the littleness of the earth on which he stood. All his life he gave a dominant place to the world, and with this as a starting point he worked out a scheme of his own for the universe. This was largely Ptolemaic in nature. He made the earth the center of all, but he said the planets revolved around the sun, while the sun and all the stars flew around the earth; this was the Tychonian system—it died with him.

Brahe was short on theory and mathematics, but he was long on observation. Somebody had to do this work, and Tycho was the man for it. Actually, he created modern astronomy, for upon his efforts Kepler and Newton built.

## 9

Tycho was the best investment Frederick II ever made. Uraniborg became the scientific center of the world. Statesmen, philosophers, and students flocked to the little island of Huen. After a bit, Tycho always had half a dozen boys working with him, learning astronomy at the feet of the master.

To the visitor who honestly wanted to know, Tycho was an ideal host. To the merely curious, he was scornful and refused to exhibit his serious instruments. Instead he brought out for them only toys, automata and the like, and let them exercise their weak wits on mechanical contrivances.

Having become a radical, Tycho remained a radical. He was no respecter of persons; he'd snub a visiting king or the crown prince as quickly as any other busybody. He had many visitors, and naturally his guests came from the nobility and court circles, but always his peasant wife was the hostess—and those who didn't like it could stay away.

Among the inmates of this strange observatory was a half-wit dwarf named Lep. He was Tycho's favorite, and no one was permitted to annoy him. He sat regularly at the table with Tycho, and when the imbecile began to mutter the guests were ordered to shut up. Tycho believed, or pretended to believe, that the fool spoke with the voice of prophecy and his half-incoherent words were carefully written down for future analysis.

Did Tycho really believe in this dwarf? Nobody knows. All his life, Brahe was superstitious. All his life he was a bit of a play-actor. Maybe, he merely used the idiot to show his contempt of chattering fools. Maybe there were, now and then, pearls of wisdom in the poor creature's words. No one ever will know. But it gives one a real picture to vision the great Brahe sitting at the head of his elaborate table and commanding his guests to be silent while a half-wit mumbled.

## 10

So for twenty years, Tycho viewed the stars from his little island and lorded it over the aristocratic num-

skulls who came to stare and gasp. James I, who, fat and pompous, had come down from Scotland to rule the stolid English, visited Brahe. The king was impressed and enthusiastic. It isn't on record that the star-gazer cared a snap of his finger about his Majesty —but at any rate James got away without being flagrantly insulted.

Among those who suffered, with results disastrous to Tycho later on, was the crown prince, afterwards Christian IV. As a child Christian followed the herd and went out to see the untamed astronomer at work. Surrounded by the usual court boot-lickers, Christian naturally got the notion he was some superior creature and wise enough to have an opinion on any subject. He tried to help Tycho by laying down the royal law on an abstruse problem. When he attempted this, he was no longer crown prince to Tycho; he was just an impertinent youngster, who needed to be put in his place. And Tycho did so. Afterwards Christian had little affection for the rough-speaking scientist. He was unable to forgive.

Another who suffered and remembered was the Chancellor of Denmark, Walchendorf. A bit of a brute, this fellow. Cold blue eyes, square jaws, broad shoulders—a hard man, useful to the soft Frederick. He, of course, went to see Tycho, though he had no more scientific interest in the stars than the stars had in him.

A dog caused the trouble. This dog is immortal. Not because James I gave him to Brahe, but because he is in the picture of Tycho's observatory. A kind of hound dog, he lies, with a hound dog's characteristic melancholy, at Tycho's feet, caring as little for stars as Walchendorf did.

This dog got in the chancellor's way. And the chan-

cellor kicked him. He kicked him more than once and he kicked him hard.

Tycho interfered. He told the chancellor just what kind of coarse-grained lout he was. He told him in detail, taking in several generations of Walchendorfs, past and to come. When Tycho got through, the chancellor was for leaving Uraniborg in a hurry.

He left hurriedly, but he took time to swear he'd ruin Tycho Brahe.

Frederick died, and Walchendorf and Christian IV joined hands to humiliate and then crush Tycho. These two men, who live in history merely because they hated Brahe, were yet powerful enough to beat him.

II

Little by little, Tycho was stripped of his resources. The Norway estate was taken from him. His pension was stopped. He had spent his private fortune in furnishing and supporting Uraniborg. He could no longer maintain the observatory. He took a private house in Copenhagen.

Still Walchendorf wasn't satisfied. He got a commission appointed to pass on the value of Tycho's astronomical work. This commission was exactly like many commissions up to the present. A commission seldom brings in a report opposed to the desires of its master. Walchendorf's body of puppets was no exception to this. Tycho's work was found to be not only fallacious, but harmful to the moral and spiritual integrity of the Danish people.

This in plain language meant that Tycho was a heretic. That's the way the good people in Copenhagen understood it, and they had no use for heretics.

Tycho was world-famous. Not only that; he had written his name among the immortals. No matter; a

greater than he had once been handed over to a mad mob.

The citizens of Copenhagen attacked Tycho. He was now an old man, and the trials and disappointments of the last few months had worn him, but nothing could break his hot spirit. Imagine him in this his last good fight. His fury burning up opposition, his righteousness trampling on hypocrisy, his courage beating cowards, he pressed through the mob, head up, defiance in word and gesture.

So he escaped to his home; so in a fierce rage was all love for Denmark burned out of his heart. Here was no peace; here was no resting place. Here were only contention and disgrace. After twenty years he took up again his journeying. After twenty years he set his face to the south, and at Prague he found a patron and friend in the ruler, Rudolph.

12

It was in June, 1599, that Tycho reached Prague. Rudolph II gave him the castle of Benatky as a home and an observatory, and granted him a pension sufficient to live on—if it had been paid.

After his wanderings—he had visited Rostock and spent a winter at Wittenberg after leaving Copenhagen—Tycho had come to the end of his journey. His work was done.

Only two things of importance happened to him in Prague. One was the coming of John Kepler. But that's another story. It was important to Brahe only because Kepler agreed to publish the great astronomer's observations. This he did as the Rudolphine Tables. How that was done you will learn later.

The other was the coming of death.

He became ill; sleeplessness and delirium wasted

him. He had no spirit with which to fight his disease. He often exclaimed, "Oh, if it is only true that I have not lived in vain!"

His friends and family surrounded his death-bed —the faithful peasant wife was at his side. On October 24, 1601, the end came.

Tycho was buried, and his beloved instruments were carefully put away by Rudolph in a museum. They were not allowed to remain there. When Prague was captured by the troops of the elector palatine, the museum was raided, and the instruments were scattered or destroyed. Thirty years later, Tycho's great brass astronomical globe was found, recognized, and sent to the Academy of Sciences at Copenhagen. And there it remains, silently testifying that Tycho Brahe once lived and worked on this old earth.

The aristocrats who drove him from Denmark, overran his island of Huen. The observatory disappeared, and today only a mound of earth remains where once stood Uraniborg—the Castle of the Heavens.

13

Tycho was no dreamer. Never could his imagination match that of a Kepler or a Newton. When he moved away from facts, he was lost. For instance, of comets, of which at that time nothing was known, he wrote:

"They are formed by the ascending from the earth of human sins and wickedness, formed into a kind of gas, and ignited by the anger of God. This poisonous stuff falls down again on peoples' heads, and causes all kinds of mischief, such as pestilence, Frenchmen, sudden death, and bad weather."

No, Brahe could not theorize but he could see. He fathered modern astronomy by setting the method of astronomical work. But he did more than that; he laid

the solid foundation upon which Kepler and Newton were to rear their magnificent structures. He did this by fighting always for accuracy. His records were so nearly exact that even with the most delicate modern instruments observers find it difficult to improve upon them.

*Chapter Fifteen*

# WILLIAM HARVEY

PARACELSUS, as we saw, downed Galen, but Galen refused to stay down. The idol, however, had tottered, and the attack on the champion who had reigned for fourteen centuries was not again abandoned.

A great Italian, who lived from 1514 to 1564, finally demolished Galen as an authority. The errors of the Greek-Roman were pitilessly exposed in Vesalius's book, "Fabrica." Here was a new voice out of Padua —the voice of one who had gone to the human body for facts.

What an uproar that book caused! Sylvius, who had taught Vesalius, turned against him, ridiculed him, heaped coarse abuse on his head. Doubtless Sylvius knew Vesalius was right, but he was playing in with the controlling faction. Columbus, a pupil of Vesalius, also knew, but Columbus was a trickster and an opportunist. All the great ones of Padua, of Italy, opposed this upstart, Vesalius, who had dared to discredit Galen.

Underground schemes and lies hit at Vesalius. It was too much. He had told the truth as he saw it, and the world hated him for that telling. Vesalius threw up his job, burned his notes, went to Spain, became a courtier, and turned his back squarely upon his genius. At fifty, he died at the very instant when he was planning a renewal of the contest.

2

His fate was less glorious and less painful than that of Servetus, whom Calvin burned in 1553. Servetus was a skeptic, with a rare, inquisitive mind. That was something Calvin could not stand. He wanted no originality in the world. So, to the stake went Servetus, one more martyr for the crime of "honest thought."

Servetus put his finger on the pulmonary circulation. He taught that the blood, after being mixed with air in the lungs, passes into the heart. Just how the blood got back from the arteries to the veins on its way to the heart, of course he didn't know. He had no microscope. But he made a shrewd guess and he paid the penalty for his daring.

Vesalius was also hot on this mystery of the blood and what it did. Half-heartedly, he accepted the Galenic idea that the blood seeped through the walls of the heart from the right to the left side. He didn't know what the blood did when it got back to the right side of the heart, and he may have been throwing a sop to his enemies when he wrote:

"We are driven to wonder at the handiwork of the Almighty, by means of which the blood sweats from the right into the left ventricle through passages which escape the human vision."

3

No, neither Servetus nor Vesalius could bury Galen. That was left for a greater man than either of them —for William Harvey, the Englishman.

Vesalius had been dead for fifteen years when Harvey was born at Folkestone in Kent in 1578. He came at exactly the right moment, and his feet were

set early on the trail blazed for him by Servetus, Vesalius, Columbus, Gabriele Falloppio, Ambroise Paré, and Andrea Cesalpino. He had but to drive ahead, and Harvey's every instinct was to drive.

Harvey's father was a farmer and prosperous; a solid, intelligent man, who gave his son a good home and a chance at whatever education was then going. He was sent to the grammar school at Canterbury and at sixteen entered Cambridge, was graduated as an A.B. at nineteen, decided to be a doctor and immediately went to Padua to study.

There where Vesalius had taught and been beaten and exiled, Harvey sat and learned anatomy. For the best part of five years he remained at Padua, and when, a full-fledged doctor, he returned to England, he was twenty-four years old. In this quiet young Englishman there was none of the storm and tempest of Paracelsus and Vesalius. It never occurred to him, as it did to each of his great predecessors, that he could take the world by the neck and shape it rudely to his way of thinking. Probably it didn't occur to him that he had anything especially new to give the world. So he settled down quietly in London as a modest young physician, hoping people would fall sick and ask him to cure them.

4

It was to the London of James I that he returned. Not much of a city as cities go now but doubtless looked upon with some pride by Harvey's contemporaries. There was still no paving, no sewage, and little or no street lighting.

But these were small inconveniences. Shakespeare and Ben Jonson were active, Jonson doing his best to make James I believe he was really welcome in Lon-

don. Romance was rife, and it was a good old world —happy for one thing because it did not know that it was on the eve of being turned sour by the Puritans.

Yes, romance was in the air of that London, and it caught Harvey. A presentable young man, was this little doctor. He was below the average in height, slender, with coal-black hair, swarthy skin, little round black eyes, which sparkled, a high, prominent forehead, and a ready, honest smile. It is not surprising that the daughter of the great Dr. Lancelot Browne, formerly physician to good Queen Bess, looked at him from behind her fan with a come-hither eye. They were married in 1605, and on the whole the sprightly daughter of a doctor seems to have made a satisfactory doctor's wife.

There is reason to believe that Harvey took his general practice rather lightly; but he must have been fairly successful and he won his way to the bedside of patients who could pay big fees. Among others, he attended the lord chancellor, Francis Bacon, and the earl of Arundel.

A canny young man, this Harvey, with his weather eye constantly alert. He got himself made a member of the Royal College of Physicians—and that was an honor not every drug-mixer could hope to win. Then, with some effective pulling of wires, he was appointed physician to St. Bartholomew's Hospital. Pudgy James I backed him for the job, which means that Harvey had already attracted the eye either of his Majesty or of someone close to the throne.

All of this happened by the time he was thirty-two years old—a creditable record. Probably his father-in-law, old Dr. Browne, helped, but if Harvey hadn't been a natural diplomat and courtier no one could have pushed him forward so rapidly. Especially since

up to this time he had done nothing in medicine to attract attention.

5

In 1616, the very year that Shakespeare's candle sputtered out, Harvey began a series of lectures at St. Bartholomew. Paracelsus's radical innovations were not for him. He stuck to Latin, as if the things he had to say were too fine for the vulgar English tongue. But, while he maintained the conservative form, his lectures were as radical in thought as anything Paracelsus or Vesalius ever dreamed.

Almost at once he attacked the problem of the motions of the heart and blood. Yet these lectures never caused a ripple in the quiet stream of medical conservatism. No course of lectures by an unknown could do much to the placid, self-satisfied English physician. Most likely what he had to say reached very little beyond the limits of his lecture room. His was not the flaming personality that makes a professor popular, and it is not on record that he inspired a single student with a burning desire to know.

All this time Harvey must have been living a staid, conventional life. One gets this idea from the fact that in 1618 he was appointed physician extraordinary to James I. When James, full of platitudes and dulness, passed on, Harvey was made physician in ordinary to Charles I.

At fifty, Harvey's name was almost unknown outside of London and was wholly unknown on the Continent; and yet 1628 was the very year that was to bring him fame and set him for all time among the great ones, along with Hippocrates and Galen. In that year he published his book on the movements of the heart and blood.

6

What was there so singular and daring about Harvey's theory? That the heart and blood moved had been known since antiquity. Down in Italy, with the help of Galileo, a lot of work had been done with the pulse. Servetus, as we saw, had written of the circulation through the lungs. Sylvius had discovered and described the valves in the veins. What then was Harvey's contribution?

Simply this: He took up the work where Servetus had been obliged to leave it, where Sylvius had been unable to go forward. He said the blood flowed in a continuous stream, over and over, through all parts of the body from the heart and back again to the heart. He said the contraction of the heart forced the blood out, and that when the heart relaxed blood flowed in to fill it. And he buried Galen when he showed that there was no connection between the right and left sides of the heart except through the lungs.

This all sounds rather stale and matter of fact today. It was iconoclastic and heretic when Harvey put it first in print. For less than this, Vesalius had been driven into exile; for less than this, Servetus had been burned; for less than this, Paracelsus had been mobbed in Basel and at last murdered.

7

Could Harvey, going farther than any one of these, escape? Not entirely. With the appearance of his book, his practice fell off—for who would trust his life in the hands of a madman? A favorite of Charles I, Harvey did not find this loss of business important, and at all times his income seems to have been ample. Yet he gave his book to the world in fear, for he writes:

"What remains to be said upon the quantity and source of the blood is of a character so novel and unheard of that I not only fear injury to myself from the envy of a few, but I tremble lest I have mankind at large for my enemies, so much doth want and custom become a second nature. Doctrine once sown strikes deeply its roots, and respect for antiquity influences all men. Still the die is cast and my trust is in my love of truth, and the candor of cultivated minds."

Cultivated minds? Calvin had a cultivated mind, but it did not save Servetus. Sylvius had a cultivated mind but it couldn't stop his abuse of Vesalius. Francis Bacon had a cultivated mind, but he damned Harvey across Europe. Or did not these men have cultivated minds? René Descartes accepted the theory instantly, and as he was an experimenter and spoke as one having authority he did more for Harvey than Harvey did for himself.

By and large, Harvey, the radical, escaped with surprisingly little criticism. Maybe he was protected by the shadow of the throne. His sixty-seven page book, written to prove that nearly everything previously said about the heart and blood was nonsense, still stands, a readable evidence of his genius.

One concession Harvey made to the age; he felt bound to say something about the soul. But what he said was a mere fluttering on the fringe of thought; it had no connection with his sound deductions from experimental science. He said the soul was located in the blood. Harvey lacked the vision to see that the soul is not in the body, but, if anything, "the body is in the soul." At any rate this was a small matter and should not rise as a criticism of the first of the English doctors.

8

So things went sailingly with William Harvey, physician in ordinary to good King Charles I, who needed a doctor if ever a king did. In 1630 he went as companion to the young duke of Lennox on the grand tour and saw most of the countries of Europe. In '36 he was with the earl of Arundel at Prague and met great doctors, some of whom still sniffed at his "circulation of the blood."

From that trip he came home to practice his profession, but Charles took him to Scotland in 1639. After that he was left alone for two or three years, and he went about his business of doctoring the fashionable people of London and writing an occasional letter in defense of his great discovery.

That was all very well, but it couldn't last, for merry England was turning rancid. Cromwell had arrived, and he and his Puritans were making a noise that was not merry. Harvey was a royalist to his finger tips, and the turmoil that boiled over in 1642 was just plain treason to him. He stuck to Charles, and at the battle of Edgehill he was with the king, behind a hedge, reading, until an intrusive bullet sent him farther away. As Charles failed to score the decisive victory expected, Harvey retired with his prince to Oxford—and thereafter let the war go its way with little help from him.

While at Oxford, he spent his time studying the growth of the chick in the shell. Every day an egg was opened, and the change that had taken place in twenty-four hours was carefully noted. In this way he gathered material for his book on generation. He put a lot of work and observation into this book, but its practical value is slight. It is worth mentioning,

because it revived the study of a subject that had lain dormant since Aristotle's time. One superstition he tried to kill—that of spontaneous generation. Ignorance, however, was allied against him, and it was not until the microscope was highly developed that this silly idea was discarded.

While in Oxford—he stayed there three years—he came near losing his place at St. Bartholomew's because he "had retired to the party in arms against Parliament." Apparently Cromwell, or someone under him, would have been glad to know something serious against the good physician in ordinary to the king. At any rate Harvey's lodgings at Whitehall were searched after the Roundheads had occupied London. Everything in the place, including manuscripts, was seized.

This was a hard blow, but a still harder one followed: Oxford surrendered to Fairfax and, for Harvey, that was the end of the world. The friends with whom he had been intimate for more than forty years were gone, driven from their old haunts. The court, in the light of which he had shone, was destroyed. As far as he was concerned, London had been wiped off the face of the earth.

Alone he could not fight these psalm-singers who had exiled joy from the island. Sixty-eight years old, and thoroughly disgusted with the ways of men, he gave up all public office and went into a seclusion from which he was not again to appear. On one occasion only was an effort made to drag him back into prominence. The Royal College of Physicians elected him president. He declined the honor on the basis of age. Probably the truth is that Harvey could not reconcile himself to an England without a king, and refused to become interested in the religious fanatics who had destroyed his country.

9

His work on the generation of animals was published in 1651. Not that Harvey cared. The manuscript could have mildewed in his trunk for all of him, but Dr. George Ent saw it and insisted on giving it to the world. "All right," said Harvey, "do what you please with it. It doesn't matter to me."

What could matter to him now? He was a childless widower, robbed of his king and of all the bright souls who had sparkled with him at the foot of the throne. Almost eighty, he was a little, white-haired old man with sunken cheeks and a snowy beard. Only the small, twinkling black eyes hinted at the gaiety gone, at the life and energy that had been a man.

No, there was nothing left in life for him, and his own words were full of utter hopelessness: "The state is agitated with storms, and I myself am at sea in an open boat."

It was January, 1649, that Charles I was executed. Eight years had come and gone to William Harvey since then, and this strange usurper, Cromwell, still rode powerfully.

But the third of June, 1657, dawned brightly for this old, old doctor, who could not save his king and who was now powerless to save himself. Paralysis struck him down, and he lay for a little while dumb, but conscious. Nephews and friends gathered around him. Silently, with weak gestures, he gave away his trinkets. So he ended matters, putting his house finally in shape. Evening came and with the setting sun, life went out of William Harvey. Surely, never did a less mournful death mark the passing of one of the world's great ones.

*Chapter Sixteen*

# JOHN KEPLER

WIFE," said John Kepler, "we are going to Prague."

"Yes?" said Frau Kepler. "And what shall we use for money?"

John looked at her out of dreamy, near-sighted eyes, as he told her: "We have enough for the trip. Once there, Tycho Brahe will look out for us."

"You've never set eyes on him. You're a perfect fool, John."

"I know, I know," replied John Kepler, "but I must see his figures on Mars."

"And you expect to drag me and the children off to Prague where you don't know a soul, haven't a job and no prospect of getting one?"

"We'll have to go." Her husband's tone was quietly final.

When he spoke like that Frau Kepler knew it was useless to argue with him. But she never stopped complaining.

She was a tall, thin woman with sharp features and a bitter tongue. And she had fits, was almost always sick, had buried one husband and divorced another and probably expected to bury John, who was a chronic invalid, given to the practice of sitting up all night, covering big sheets of paper with long rows of figures that meant nothing to his wife.

2

Kepler didn't look exactly sick, but he was never absolutely well, and he was subject to frequent serious attacks that threatened to end fatally. As a boy he had nearly died of smallpox and was permanently scarred by it. He had gone down again with scarlet fever, and had bad eyes and a weak constitution as a result. He had had a bad start in life, as he was a seven-months baby, born December 27, 1571, at Weil—and seven-months babies are proverbially weak in mind or body or both.

But John's mind, as a boy, had seemed all right, and he did well in school at Leonberg. That didn't last long, because his father got in trouble. He foolishly went surety for a friend and, when the friend disappeared, John's father had to pay. He paid and was left next door to a pauper. In some way he got hold of a tavern—not very different from the saloon Americans knew a few years ago. The business didn't pay much, and John was taken out of school and put to work running errands and keeping the pothouse scrubbed.

A thin, sickly boy he was, not strong enough for such dirty, hard work. He'd far rather read a book than carry a pail of beer around the corner to a fat Dutchman. John's father was good-hearted, and he hated to see his little son turned into a slavey, so when a chance came to send the boy to school, free of charge, he jumped at it.

3

When John heard he was to go to school he was radiant. His joy was so great that it made him nearly ill. He was so anxious to escape from the pothouse that he hardly would take time to tell his friends good-bye.

But he threw his arms around his father and held him with all his little strength. It was good to remember that in after years, because he never again saw his big, fun-loving father.

He wasted no time on his mother. Even then he realized that affection meant nothing to her. She was a hard-talking, narrow-minded woman, to whom love was just a word. He could leave her, and the place she called home, with no regrets. Obviously his father felt the same way about it, and John hadn't been long at school when he heard that his father had gone away. That was the end of this shadowy father of John Kepler. He may have died somewhere in Holland or England. Anyway he never returned to the scolding wife and the miserable little German home. Did he live long enough to know he had fathered one of the world's great men? Probably not, though fame came early to John Kepler.

4

When John Kepler had finished the university course at Maulbroon, he was offered a job as professor of astronomy at Gratz. He hated the idea. Astronomy was not a science. It was little better than fortune-telling. Mathematics was what John loved. But he was given no choice in the matter and he grudgingly accepted the post. The world was forever the gainer by that decision.

John did not know much of what little was known of astronomy then. He had heard lectures at school, of course, and had a fair notion of the Copernican theory. But he had never made an observation, and to him the stars were just bright things in the sky. It was characteristic of this conscientious German that, having taken the job, he should start studying his subject. He was stimulated and soon intensely interested. Here was

room for the free play of the finest imagination ever given to man. He swept into his subject on the wing of uncontrolled hypotheses, and for all the rest of his life he was as a law-giver of the heavens.

The planets fascinated him. His strangely speculative mind told him there should be some relation between their motions and their distances from the sun. But first he tackled the somewhat simpler problem of their orbits—that is, how to account for their exact distance from the sun. He tried many things, but none of them worked out just right. Then he hit upon what seemed to him a magnificent idea.

He knew that there are only five regular solids—that is, solids where the sum of the plane angles at the corner is less than four right angles. Of course there are any number of solids of irregular shape, as crystals and the like, but there are only five of these regular solids. With these solids Kepler, now twenty-four years old, tried to solve the riddle of the planets.

Around one solid, the dodecahedron, he drew a sphere. The orbit of Mars lay in this spherical surface. Around this circle he drew a tetrahedron. The sphere circumscribing this, he said contained the orbit of Jupiter. And so with the other three regular solids he got approximate orbits for all the planets then known.

He spent days and nights over this meaningless hypothesis and when he finished his figures he was so delighted that he regretted not a moment of the time given to the exacting and thankless task. His results, along with a good deal of metaphysical nonsense and weird reasoning, he published in a book to which he gave the high-sounding title of "Mysterium Cosmographicum." Today, of course, it is worthless, but it remains an evidence of the genius and diligence of a twenty-four-year-old boy.

## 5

When it came to the relation between the speed of the planets and their distance from the sun, his problem proved much harder. The planets farthest from the sun moved slowly. But why? This young man wanted the reason back of the known facts. His explanation, at this time, was vague, for he says:

"Maybe there is one moving intelligence in the sun, the common center, forcing them all around, but those most violently that are nearest, and that it languishes in some sort and grows weaker at the most distant, because of the remoteness and the attenuation of the virtue."

Obviously, when this was written, Kepler had some glimmering notions of universal gravity, but this idea was certainly far from clear in his mind. He felt that the sun not only drew the planets, but at times drove them away. Only thus could he account for their varying distances from the common center.

All his efforts to find for the planets a connection between their distance and motion failed, and he gave up the problem when he found he was working in a circle.

Among others, Kepler sent a copy of his book to the great observer, Tycho Brahe. The Dane thus became interested in this young man who was stung with the desire to know and he suggested that his observations made at Uraniborg would simplify Kepler's problem. Tycho was then at Prague. And so John said to his wife, "We must go to Prague."

## 6

All his life John Kepler had faced two serious handicaps. Poverty and sickness. He could not have been

a very attractive young man. He was indifferent to clothes even when he had the money to buy them. He spent so many hours over his books and problems that he had no time to learn the small graces of society. He had no light chatter with which to amuse a thoughtless girl. But John was emotional, enthusiastic, and sentimental. And he wanted to get married.

The woman who captured his fancy was twice a widow—but she was reported to have a fortune. It's impossible to believe John was not influenced by that consideration. There is nothing in his whole life to indicate that he was ever the victim of a blind passion. If he could get a housekeeper and a fortune at the same time, his troubles would be over.

The lady was ready to say yes, but her family interfered. They wanted to know if John belonged to the nobility. John did. It took some time and effort to establish that fact, but eventually he got the proofs.

So they were married—and did not live happily ever after. Not by a considerable margin. In the first place, the widow's fortune could not be found. John blamed the relatives. Those sticklers for nobility apparently had deceived the impractical John. He quarreled with his wife's relatives, and then went about the business of carrying a burden too heavy for his weak shoulders.

John's decision to go to Prague was not the result of hasty impulse. He had several letters from Tycho and reached a fairly clear understanding before he decided to go. "Come not as a stranger," wrote Tycho, "but as a dearly beloved friend."

7

It was a long way from Gratz to Prague, and a hard, wearisome road. Frau Kepler and the children stood the strain well, but John, excited by the thought of

all the great folk he was to meet in Prague—maybe the powerful Rudolph himself—had an attack of nerves, fell ill, and for weeks was laid up at a wayside inn.

Now, indeed, the question of money became urgent. Sickness among strangers is expensive. The small sum, their all, that the Keplers had brought with them was soon spent. Sick, far from home, penniless and with a wife and children dependent on him, John Kepler lay wondering whether he was going to die, wondering whether his family would starve. Back in Gratz were friends who would help a stricken philosopher, but Gratz was far away. Prague was not now distant. And in Prague was Tycho Brahe. Word went to the Dane, an appeal, a cry out of distress. It did not fall on deaf ears.

Tycho sent money.

Relief from worry quickened John's recovery, and soon he and his family were in Prague. There Brahe and Kepler met at last—the far-seeing one with a silver nose; the short-sighted one with the wasted form and no strength to endure the chills of night. The one saw, as no man before him had seen, all the things that were set in the sky. The other's thought sped beyond those planets and twinkling suns, into boundless space, where he groped for universal laws. They had nothing in common, these two, but a desire to know—and the starry heavens for a treasure-house.

Tycho was robust, dominant, the child of luxury and of privilege. A slayer of conventions; a candid, blustering soul as empty of imagination as a tin pail.

John was as gentle as an evening wind, a soft-spoken, friendly man. He had no strength, but he had perseverance. He had rare, beautiful dreams, and he struggled through midnight hours in a tireless effort to

make his dreams add up to a definite sum. With him, to fail was simply to start again on the trail of a new flaming fancy. Tycho was all eyes. John was all mind. Tycho was the man for his work, but it was Kepler who had to pick up the unfinished task, tell Tycho what it all meant, and cover it with the gold of immortality.

8

Here was a fine friendship, springing mushroomlike in a night. It was after Tycho had been disgraced, mobbed, driven from Copenhagen. The glory of Uraniborg was wiped out. This proud democrat knew what it was to suffer. In Kepler he found one who all his life had known only stress and strain. They warmed to each other—these two lonely souls. "Come as a dearly beloved friend." That was no empty phrase. And in that spirit Tycho received John and his family in Prague.

But Kepler's wife worried and fretted. She was far from home, far from her relatives, and she hated Tycho. His attitude of affection for John could not hoodwink this bitter woman, who having had three husbands thought she knew men.

No one knows exactly what happened. If you lay the blame on Frau Kepler, the chances are you won't be far wrong.

"It is true, then," John thought, after endless hints from his wife, "that Brahe is not treating me fairly. He has the ear of Rudolph. Surely something could be done for a master astronomer with the help of so powerful a prince. Tycho lies and is a traitor to our friendship. We must leave Prague. And Mars remains unconquered."

They left Prague, the Keplers, using Tycho's money to meet traveling expenses. The gentle John was furi-

ous with the man he had called friend and to whom he was heavily in debt. He was in such a rage that he had to write Brahe telling him when and how he had failed as a friend.

9

Fortunately Tycho was no longer the flaming aristocrat whose temper had led him into many quarrels. Time and disappointment had calmed him, and something closely resembling tolerance had forced its way into his mind. Besides, he honestly liked Kepler and he had correctly understood the nature of Kepler's wife. John's abusive letter roused no anger in his heart. It was simply a misunderstanding. John must be told the facts. He turned the letter over to his secretary.

"Answer this," he said. "You know as well as I how I feel and what I think. Make Kepler see the truth."

The secretary's letter reached Kepler in his temporary home as he lingered near Prague. He read it many times, and the words burned into him—scorching him with a hot shame. He saw now that he had listened to the voice of the tempter while his reason slept. Quick, then, with pen and paper that he might humble himself before the great Tycho. He humbled himself. No man ever did so more contritely, more thoroughly.

"Whatever I have said or written," he told Tycho, "against the person, the fame, the honor, and the learning of your Excellency; or whatever, in any other way, I have injuriously spoken or written (if they admit no other more favorable interpretation) as, to my grief, I have spoken and written many things, and more than I can remember; all and everything I recant, and freely and honestly declare and profess to be groundless, false, and incapable of proof."

Apology could go no further. He had been wrong

and he admitted his error without the shadow of an excuse. Tycho was delighted and a little bewildered by John's letter. He wrote at once, begging Kepler to return to Prague.

10

"Wife," said Kepler, "we are going to Prague and to my dear friend, Tycho Brahe."

Kepler went joyfully toward Prague and toward the reunion with the friend he had lost and found again. When they met, John started to repeat what he had already put on paper, but Tycho stopped him.

"What have we two to do with the past!" he asked. "You are my friend and you have come back to me. Enough of that. Even while you were away I arranged for you an audience with Rudolph. Great things will come of it. Your troubles are past. All except those Mars gives you. Him I turn over to you. He's enough for any one man to worry about."

Indeed, great things did come of the meeting between Kepler and Rudolph. Great, at least, they seemed to the astronomer at the time. "Imperial mathematician" was the title bestowed. And it carried an income sufficient for all needs—if it could only get paid from a cashbox rapidly growing light. The size of the promised pension mollified Frau Kepler, and life, briefly, looked bright to them all.

Those were happy days for Kepler. He was studying Mars, striving to make the planet give up its secret. But there came a sad and painful event, and for a time Mars was forgotten.

11

A candle sputtered in Tycho Brahe's room. Tycho was in bed, and John Kepler sat on a stool, listening

to his friend's last words. For Tycho Brahe was dying. John, the weakling, the never-well, was watching the strong, the never-sick, end his boisterous journey.

"All my life I worked at the stars," Tycho said. "I wanted tables that would be accurate and I set my goal at a thousand stars. Now I have come to this—and only seven hundred and fifty are finished. I should have ended this work, but my king, my country turned against me. There was a long interruption and now you, my dear friend, must carry on my work. All my papers I leave to you. Publish my observations as the Rudolphine Tables. That much we owe to our prince. You will not fail me?"

Fail? Not John Kepler. Given is that promise, with no thought of the hardship and drudgery involved in keeping it.

"Only seven hundred and fifty," muttered Tycho. "A man's work yields to his enemies. My work is done as well as I could do it. The tables will live. I throw to navigators a safety-line."

John sat still, tears tumbling down his bearded cheeks. Silence filled the room.

12

"Principal Mathematician to the Emperor." That was the title the paranoic bachelor king of Bohemia and Emperor of Rome bestowed upon Kepler after Brahe's death. John, with the appointment duly signed, sealed, and delivered, felt that his troubles were all behind him. It was at this time that he treated himself to the fine fur-trimmed coat that the centuries have made a part of him. A fine looking man he was when rigged out in that coat, with a round, flat scholar's cap on his head and full beard covering his pockmarked face.

He was now, he thought, in a position to finish Tycho's tables. All the great Dane's papers were in his hands and he started work on them. Brahe's busy relatives interfered, claimed the manuscripts, took them away from Kepler. All but the observations. These John kept that he might fulfil his promise and publish the Rudolphine Tables.

Kepler was a little vague as to his exact duties in his new elevated position. This vagueness was soon dispelled. Rudolph wanted a fortune-teller—to read the stars and forecast the future. It was nonsense; it was a silly superstition, and the astronomer knew it. But Rudolph needed a fortune-teller. Affairs in Bohemia were getting into a mess. Rudolph was not the man to straighten them out. Vacillating, neurotic, half-mad, this poor shadow of a king could only let things go from bad to worse, get hopelessly involved, watch the spirit of intolerance and bigotry lay the sputtering trains for the explosion that started the Thirty Years' War—the bloodiest and most cruel of the wars of men.

A fortune-teller? Had an inspired seer ripped away the curtain of the future, Rudolph would have died of pain and horror.

Kepler hated astrology. To him, the stars were beautiful enigmas whose secret laws he was determined to know. Beautiful and remote! Not concerned in the small things that crawled, on two legs, across the face of the earth.

Yet Kepler turned astrologist and gave Rudolph his horoscopes. A mean work for humanity's greatest imagination! But the mathematician's family had to live, and the salary the king had promised him was not paid. Promises, sight drafts, and the like, he got in plenty; but these could never be turned into hard cash. Horoscopes, however, brought in money, and John

went into the business of casting nativities. In spare moments he labored with Mars.

13

He tried many weird fancies, wild-goose chases, in his effort to discover the relation between Mars's distance from the sun and his speed. He knew there must be a law and he meant to find it. As it again and again escaped him, he momentarily gave up the task and gave his energy to the Rudolphine Tables. What he needed most for them was money. He appealed to Rudolph, but the king's exchequer was empty. There was no help to be had at the royal hands. So in turn he had to put away the tables.

Just at this time, a new star appeared in Cassiopeia. This gave John a chance to take a rap at astrology and he proceeded to do it thus:

"What this new star may portend is hard to determine, and this much only is certain, that it comes to tell mankind either nothing at all or high and mighty news, quite beyond human sense and understanding. First, it portends to the booksellers great disturbances and tolerable gains; for almost everyone remarks upon it, and will wish to bring these remarks to light. Just so will others, learned and unlearned, wish to know its meaning, and they will buy the authors who profess to tell them. I mention these things merely by way of example, because, although this much can be easily predicted without great skill, yet it may happen just as easily, and in the same manner, that the vulgar, or whoever else is of easy faith, or, it may be, crazy, may wish to exalt himself into a great prophet; or it may even happen that some powerful lord, who has good foundation and beginning of great dignities, will be cheered on by this phenomenon to venture on some

new scheme, just as if God had set up this star in the darkness merely to enlighten them."

This should pretty well clear up Kepler's position on star-gazing and fortune-telling.

14

Since there was no money for the tables and no immediate chance of mastering Mars, John turned his attention to light. He studied and wrote on the refraction of light in dense mediums. He didn't get very far with it, and the real work was left to future investigators. It was while he was engaged on this that he heard of Galileo's telescope. This set him to working out the principle, and he reached a surprising conclusion. He said that two convex lenses should be employed, so that there would be a real image, where measuring wires could be used for reference. Having thrown out this sage hint, he let it go at that and did not try to make an instrument. That was left for Gascoigne, of England, who followed Kepler's idea and made what was universally known as the "astronomical telescope."

All this time John was more or less busy with trifles, working at his job, trying to earn the wages he could never collect. In 1606 he wrote another paper on the new star. The purpose of this was to refute the idea that the strange star was a "fortuitous concourse of atoms." To him it was a star like any other, which had suddenly come within light-range of the earth. The next year when a comet, now known as Halley's, swept across the sky, he wrote a book about it. No superstitious notions for Kepler. To him a comet was a planet moving in a straight line. He assumed that comets did not belong to this universe. If he hadn't made that mis-

take he might have preceded Halley in the comet theory.

One thing he did say in this book that showed he was the real master mind. The planets, he insisted, shone by their own light; otherwise they ought to show phases, as the moon does. Galileo was soon to reveal the truth.

Kepler wasn't above making mistakes but he was man enough to acknowledge errors when they were pointed out to him. For instance: In 1607 he published a hurried account of an observation of Mercury crossing the sun. Not long after came Galileo's discovery of sun-spots, upsetting Kepler's deductions. Kepler at once cheerfully struck out his Mercury theory, and admitted widely that Galileo was right.

15

There were a lot of foolish notions floating around Europe at that time and the Copernican theory was far from being generally accepted. The church still had its face set against the idea. But, vaguely, John was evolving a theory of gravity; and in his "Commentary on the Motions of Mars," he wrote:

"Gravity is a mutual affection between cognate bodies towards union or conjunction (similar in kind to the magnetic virtue), so that the earth attracts a stone much rather than the stone seeks the earth."

There was the idea that Newton was to take and build into a bold and splendid theory, bolstered by mathematical proof. But to Kepler there seems never to have come more than a faint notion of universal gravity. It was right around the corner from him, and he certainly saw its shadow, but the thing itself never appeared.

16

Kepler mulled over Tycho's tables. He found a lot of strange things there, and, as he followed the course of the planets, it seemed to him that there must be some law or laws governing their movements. In his determination to make Mars tell him the truth, he always worked from some dazzling hypothesis—mostly one that turned out to be foolish. But while working at the orbit of Mars he made one real discovery that is now known as Kepler's Second Law:

"The straight line joining a planet to the sun sweeps out equal areas in any two equal intervals of time."

Having made this law secure, he went on and tried to find the exact path in which Mars moved. Aristotle and the Greeks, as you know, had insisted that the circle was the perfect curve, and that, therefore, everything in the heavens must move in a circle. Kepler tried a circle. It wouldn't work. He couldn't make Mars come right within eight minutes. He knew that Brahe was never eight minutes wrong in an observation in his life. He was sure the error was his—not Tycho's.

"With those eight minutes I'll yet unlock the secrets of the heavens," he cried.

At last he decided the orbit could not be a circle. Then he went after ovals, arbitrarily choosing their shape. Some of these fitted fairly well but none of them perfectly. All of this work was sapping his strength and it was driving Frau Kepler mad. Things had been bad enough when he dealt with circles, but his task was enormously increased when he took up ovals. He covered sheets of paper with figures. Still the thing wouldn't come right. Once he thought he had succeeded and he started to celebrate. But in predicting the position of Mars errors soon appeared. Wrong

again. Was there no end to it? He insisted there should be an end, because he was sure there was a law and that he would find it.

Just at this time, when he had practically exhausted the ovals, one of those unbelievable accidents happened.

John was dreaming over his figures. It seemed to him that he had tried everything, and he was discouraged and sick and tired. He ached with the labor of gigantic computations—now seen to be worthless. The secret was there but it escaped him. Should he give the whole thing up? Idly his wearied eye ran over the figures in front of him; it was arrested by two numbers. Their similarity struck him, and something deep and thrilling stirred in his mind.

What he saw were 1.00429 and .00429. One, the first, expressed the greatest optical inequality of Mars. The other was half the distance between an ellipse and a circle. Genius whipped him. Here was his figure, here was the thing to make the desired orbit. Feverishly he set to work. His results convinced him he was right. Let him tell it in the words of triumph he used when he gave his discovery to the world:

"What I prophesied two-and-twenty years ago, as soon as I discovered the five solids among the heavenly orbits—what I firmly believed long before I had seen Ptolmey's Harmonies—what I had promised my friends in the title of this book, which I named before I was sure of my discovery—what sixteen years ago, I urged as a thing to be sought—that for which I joined Tycho Brahe, for which I settled in Prague, for which I have devoted the best part of my life to astronomical contemplations, at length I have brought to light, and recognized its truth beyond my most sanguine expectations. It is not eighteen months since I got the first

glimpse of light, three months since the dawn, very few days since the unveiled sun, most admirable to gaze upon, burst upon me. Nothing holds me; I will indulge my sacred fury; I will triumph over mankind by the honest confession that I have stolen the golden vases of the Egyptians to build up a tabernacle for my God far away from the confines of Egypt. If you forgive me, I rejoice; if you are angry, I can bear it; the die is cast, the book is written, to be read either now or by posterity, I care not which; it way well wait a century for a reader, as God has waited six thousand years for an observer."

17

In 1609 Kepler published his "Commentaries on Mars." Two of his great laws were given in that book. The second, uncovered first, dealt with equal areas in equal times; and the first is:

That the planets move in ellipses with the sun in one focus.

These two clarifying laws, to which he later added a third, that the squares of the periodic times of the planets are proportioned to the cubes of the mean distances from the sun, won for him the name, "Law-Maker of the Heavens."

He was thus famous: he had a high-sounding title at the court of Prague—but he was still penniless. And he could not get the Rudolphine Tables published. He wanted to give those tables to the world. He had given his promise to the dying Tycho and he was determined to keep that promise. Meanwhile a famous astronomer must live.

Bohemia was in a bad way, financially and politically. Rudolph, always a little mad, was sinking into melancholia—into lethargy. He was indifferent to

everything except the stars; he was still interested in what they had to say about him and his small doings. It was for Kepler to furnish this far-dragged information.

He hated the work. But he did it, and his fortune-telling proved as reliable as that of any other sham star-gazer. And since this seemed the only way to an income, he became a professional fortune-teller, his fame and his title creating a demand for his horoscopes.

18

Here was as fine an imagination as ever flamed in a human head held to the mechanical task of telling little men what the stars held in store for them!

"Wife," said John Kepler, "we'll get out of Prague."

"Yes," said Frau Kepler, "let's go home. Rudolph is no better than a lunatic. He'll do nothing for us."

"You're right. But we won't go home. There's no work for me back there. I'm going to Austria. There's a chance at Linz."

He went there in 1610, and a position was promised to him. But when he got back to Prague, he found things in a turmoil. Rudolph was being urged to abdicate. Frederick was in one hostile camp, Matthias in another, and war was in the air. He found his wife sick. Hungarian fever, aggravated by epilepsy, had sent her to bed. She was slowly recovering, when the three children were stricken with smallpox. One of them, Kepler's favorite son, died, and the others were a long time getting well.

Rudolph died, and Matthias came to the throne. The new king did not care about astronomy, but he reappointed Kepler imperial mathematician—yet could find no cash for him. Then, in an effort to get rid of an obligation and an annoying subject who

wanted to be paid, he gave John to the great Wallenstein, who agreed to pay all arrears of salary. But Wallenstein wouldn't or couldn't meet the obligation.

19

The plague was in Prague, and war was everywhere. "This is no place for me. This time I'll get out for good," said John. He made a second trip to Austria and was named to the university at Linz. There his salary would be paid, and maybe he could find some way to publish the Rudolphine Tables. The way ahead looked bright and clear.

Happily he returned to Prague for his family.

But this man, this giant among dreamers, was marked for misfortune.

Frau Kepler was again ill. Grief and worry and a bad constitution had been at last too much for her. Never again would her voice be raised in shrill denunciation or tearful complaint. When John entered her room, death was already crouched at her side. He held her hand, this man who had never loved the mother of his children, and looked long into the tired eyes of the dying woman.

There was little that these two intimate strangers could say to each other in that last hour. Homely words, meaningless and cold, were all that they could mutter. It was soon over, and John Kepler was a widower with two small children and no money and no resources.

20

Now comes a curious chapter in the history of a great man. Kepler went acourting. Apparently he had become accustomed to having a woman around the house and he wasn't comfortable without one to look

after him. He had two small children and he didn't have anything else. His income at Linz was a trifle. He still drew horoscopes, but there was no fortune in that work. He was famous, but he was indifferent, absent-minded, and unromantic. Nobody ever called the near-sighted, squat German handsome, and his temper had become uncertain.

A more surprising figure never went out in search of a wife.

Kepler was systematic and in deadly earnest in this quest.

He made overtures to several women. Some of them flatly refused him. Some of them he cut off the list as undesirable. There were about a dozen that he seriously considered. More than one of them had money, but he seemed to have had enough of marrying an heiress. He checked them over, noting the characteristics of each. This one was too fat; that one too tall; some of them didn't know anything and couldn't learn. One of them kept him dangling for three months until Kepler, in disgust, struck her name from the list.

His friends took a keen interest in this courting. They piled advice on him and went to great trouble to seek out suitable prospects. But in the end John made his own choice. It isn't on record that he ever said a word of love to any one of the women he approached and probably the idea of love never entered his head.

When he announced his choice his friends were scandalized. They told him he was making a fool of himself, and asked what under the sun would he and his family live on.

He had chosen as his bride an orphan, the daughter of a cabinetmaker, who had for twelve years been in school at the expense of the Lady of Staryenburg.

"Her person and manners are suitable to mine," Kepler wrote. "She can bear to work. She is middle-aged and of a disposition and a capability to acquire what she still wants."

What a picture, uncolored by sentiment, of this middle-aged bride! "Person and manners suitable to mine." Ah, well, that was more than he ever said of the first Frau Kepler! A quiet, soft-spoken girl, one gathers. Not beautiful, but not dumb. An orphan, whose way had been none too easy, for "she can bear to work." Surely the wife of John Kepler will be called upon to bear work, to bear neglect, poverty, pain—and children.

Did Kepler's great name dazzle this orphan? Was there something in the man's soul to which her womanhood could cling? Did she weave a romance out of this marriage and develop a love for her husband? One knows only that in his home, at last, Kepler was happy. For all the rest of his life the "person and manners" were suitable. His second choice proved as wise as his first was foolish.

21

Poverty still dogged Kepler. His salary at Linz was unpaid. The state was in convulsions. Religious disturbances, later known as the Thirty Years War, were sweeping Central Europe into chaos. Kepler himself was attacked by the Jesuits—and excommunicated. His library was sealed, and only imperial protection saved him from prison—and worse.

In such times he was again forced to turn fortune-teller and issue a "vile prophesying almanac, which is scarcely more respectable than begging. The emperor abandons me entirely and would suffer me to perish with hunger."

The "vile almanac" kept him from starving and gave him time to do one of his most magnificent pieces of work. In 1619 he published "Harmonics," a work in five books, dedicated to James I of England. This is a strange volume. Some of it is of sound scientific interest; much of it is clap-trap. For instance, in the fourth book he writes of the earth as if he really thought it were an animal and wonders whether, in the depth of it, anything could be found "to supply the function of lungs or gills."

In the fifth book he writes a lot about the harmony of the spheres, a gray notion dating from Pythagoras. He seems to have had only the vaguest idea concerning it, and he gives his readers nothing to get their teeth into. But in this same book he announces his magnificent third law for the motion of heavenly bodies. This law that "the squares of the periodic times are proportioned to the cubes of the mean distances," had been illusively buzzing around in his head for a long time. He felt, intuitively, that there must be among the planets some relation between speed and distance.

This was the crowning point of all his labors. For more than twenty years, he had been in search of this law. During that time he had followed hundreds of harebrained hypotheses. He had worked at gigantic computations with a perseverance seldom equaled in the history of science. A multitude of personal distresses and the failure of patrons to furnish him with money were unable to stop this indefatigable worker. The law was there—of that he never doubted; and without benefit of logarithms or any clear idea of universal gravity, he labored at the tremendous problem.

Fancy to yourself the oceans of paper he must have covered with figures; the endless hours he spent at night, alone, in a badly furnished home, with an ill-

smelling lamp or a sputtering candle throwing a dim light across his table. Sick for much of the time, in poverty all of the time, burdened by the death of his friends, by the death of his wife, by his quest for a new wife, by his duties at the university, by his compilation of a "vile prophesying almanac," attacked by the church, excommunicated, and surrounded by confusion and war, he yet found time to carry through, successfully, one of the most profound and involved computations known to science. What a man!

22

Kepler's mother, the virago who had driven her husband into exile and given scant love to her sick son, still lived—an old woman, tough as hickory. Kepler was in Linz when word reached him that his mother was in prison and likely at any moment to be subjected to torture. He started instantly on the long journey to Wurttemberg. He must save this woman from the torture chamber.

Dame Kepler was accused of witchcraft. She was a tight-fisted, high-tempered, quarrelsome, talkative scandalmonger. For years she had been pushing a lawsuit against a neighbor woman whom she accused of slander. The defendant was charged with having said that Dame Kepler had concocted and administered a poisonous potion. After endless litigation, the tables were turned when a new judge came to the bench, and Dame Kepler found herself in prison, branded as a witch. She flew into a rare rage when her enemy so cleverly turned the attack. But now her sharp tongue and senseless anger could not help her.

"Confess or be tortured." That was all the court had to say to her. It was a brainless practice that brought a painful end to many a good witch.

The famous son arrived in Wurttemberg in the nick of time. His power and prestige were sufficient to save his mother from the rack. They were not great enough to get her out of jail. For a year longer she lay there, nursing a fine hate. When at last the case against her was dismissed and she was set free, one would think she would have been ready to keep clear of the law. Not she. Instantly she started action for costs and damages.

But one enemy stopped her. Death stepped in and stilled those lips that had spat out so many sharp words.

Kepler was not with her at the end. He was back in Linz, struggling to get paid to him a little of the money due him. What were his thoughts when this news reached him? She had been a hard mother and for many years the world had been his home.

A strange, bitter old woman, she blusters thus, unexpectedly across the pages of history and then is silent forever.

23

One piece of work remained for Kepler. He had still to keep his promise to Tycho Brahe and publish the Rudolphine Tables. By strenuous effort and personal appeal he managed to get a few hundred florins out of the state treasury at Vienna. This was not enough; it was a mere stopgap. God knows where he got the rest of the money; but he got it; and in 1627 the tables were given to the world. To appreciate the value of these tables one need know only that for more than a century they were the sole basis for the calculations every seafaring man had to make if he wanted to keep his ship afloat and himself alive.

They were accurate, they were complete; that is to say, they were priceless. As a mark of their importance

the grand duke of Tuscany sent Kepler a gold chain. Galileo, probably, had a finger in that pie. At any rate the chain was worth money. Doubtless it went to buy food for the Keplers.

24

With the appearance of the tables, Kepler's work was done. Not that he realized it! He planned great things in that imagination-lighted head of his. He planned and dreamed, while reality forced him to scheme for money. There was a large amount due him, but Wallenstein was unable to pay and no one else was disposed to listen to a mere scientist when there were such fine things to do as murder Christians at the behest of some numskull king.

The murdering went on gaily, thirty years of it; and always money could be found to hire the butchers or they were willing to work at their brave trade for nothing. All of this flashy and useless activity was carried on while the man who had searched the heavens and disclosed three great laws, and who asked only enough to put food in his belly and shelter over his head, begged for what was his own.

The spirit of old Dame Kepler lived in the genius of her son. He also would never give up. By rights the money was his, and he needed it to stop the wailing of his children. One more effort, then, one determined appeal by a man who would not take no for an answer.

On a bleak fall day John Kepler told his wife goodby—that wife whose person and manners were suitable to his. He climbed to the back of a horse and set out, turning in the saddle to wave a last farewell. Yes, a final farewell. He was leaving Linz for the last time. He thought his horse was headed toward Prague but,

indeed, he was taking the first steps on a much longer journey than that.

Kepler was fifty-nine years old when he made that forlorn effort; fifty-nine, and he had never been well. It was a hard trip. There were storms, bad beds, bad food, and at the end nothing but disappointment. John argued and entreated, but his words fell on the ears of those who were unable to help him. War had drained the city, the state. There was no cash to be raised in Prague.

## 25

It was the end. Nothing to do, John Kepler, but mount your horse and ride homeward. More pitiful figure of a man never rode through the gate of any city. Philosopher and scientist, yes, if you looked well into that troubled face, into those near-sighted, dreaming eyes. But all one could see at a glance was an old man, sick and beaten, sagging in his saddle as he rode into the gathering dusk.

What to tell those loved ones who were watching for his return? He could only show them his empty hands, his empty pockets. And they depended so completely on him!

It was November, and the dead leaves lined his road and the trees held up naked branches giving him no cheer. There were cold winds and cold rains, and the fighting spirit had gone out of John Kepler. He could only huddle in his saddle and cling tightly, trusting to the horse to keep the path that was blurred before his fever-brightened eyes.

At Ratisbon he dismounted for the night. Next day he was unable to rise. All day he lay in bed, cursing the delay, fretted by his desire to be at home. "In the morn-

ing I shall be better. I am accustomed to these attacks. They never last long." But in the morning he was not better. The fever rose. The shadows closed around him and the voices of the attendant strangers grew faint.

What were his thoughts? He was religious, and possibly his mind dwelt on God and the future. The end came with merciful swiftness. In the little town of Ratisbon, in 1630, John Kepler died.

26

For the most part Kepler met life, as he met death, alone. Briefly he was aided, as we saw, by Tycho Brahe. Before and after that short interlude, he made his fight unassisted. A king gave a fine grant to Brahe; there were dukes back of Galileo, and the state helped Newton. Kepler, sick and in poverty, could find no patron to provide for him.

But nothing could stop this man. He stumbled, but he stood up again. He failed and failed and failed; but he made light of his failures and, picking them up, builded them into a tower from the top of which he grasped celestial laws. In spite of his weak and ailing body, he defied the heavens, and his defiance won him an immortal triumph.

*Chapter Seventeen*

# GALILEO GALILEI

IN the last half of the sixteenth century, Italy was bound hand and foot by the traditions of Aristotle. They were considered infallible, and it was all one's life was worth to disagree with them. Yet the god of genius had been kind to Italy. She had been given many great men—whom she spurned, or destroyed. Leonardo da Vinci, one of time's most universal geniuses, had not dared to let his light shine too far. For more than two hundred years his scientific notes and anatomical drawings were hidden from the world.

Leonardo knew much of the human body—muscles, veins, valves, brain—everything, in short, that could be seen without the aid of a microscope. His drawings, made from dissected subjects, were masterpieces of accuracy. Yet Leonardo does not belong to the story of science, as his work disappeared at his death and everything he did was done by others before his priceless notes were resurrected.

Servetus and Vesalius, as we saw, had doubted and dared and paid for their temerity. No, Italy had no lack of great men, but her great ones lived, or died, in the shadow of a jealous power, and the terrible hand of the Inquisition was constantly stretching out to grasp them. Many weary years were to pass before the church awoke to the fact that the Bible is not a treatise on science.

2

Into such an Italy, Galileo Galilei was born on February 15, 1564, at Pisa, almost within the shadow of the leaning tower. That tower is to play a big part in the life of this ruthless youngster, now kicking lustily in the arms of his young mother.

No one cried out to the scholars in the universities, who were placidly drooling out Aristotle's errors, that the Destroyer had been born. A new baby in Pisa? What of it? We have the mold ready for him. We'll just pour him in, and after a bit he'll come out fashioned like the rest of us. That is always the dream of the schoolmaster who is first cousin to the Button Molder. But if this boy, Galileo, should refuse to go into your mold? If he should kick your mold to pieces and you with it? Then the church will deal with him, and may God have mercy on his soul.

In fact, those old fellows came shockingly near getting Galileo into their mold. As near as making him a novitiate, for he had a religious turn of mind and early determined to become a priest in the very church that later was to clamp its iron hand down upon him. But for an attack of eye-trouble the church probably would have got him.

This inflammation of the eyes gave his father, Vincenzio Galilei, an excuse for taking his son out of the hands of the monks of Vallombrosa, near Florence. Never again did Galileo get close enough to the church to think of devoting his life to religion.

Other interests immediately caught him, for he had an active and inquiring mind. Anything in the shape of machinery fascinated him; and he spent many of his boyhood days constructing mechanical toys—a business that was not looked on kindly by his father.

3

This Vincenzio Galilei was a sort of decayed nobleman. His ancestors had been lords of Florence during the life of the republic. Lately the lording business had passed into other hands, and Vincenzio, intelligent but a pauper, had little ease and comfort in his life. He was a first-class mathematician, a skilled writer on music, and the champion lute-player of Italy. But these accomplishments were not easily transmuted into gold, and as a result Galileo's boyhood home was poverty-stricken.

Not surprising, then, that Vincenzio was determined Galileo should not be a musician or a mathematician. For those two things, he knew there was no market in Italy. But everyone wore clothes, and so a cloth merchant might hope to keep the wolf away without too much effort. Hence the clothing business for Galileo.

But first let him learn a little something, because after all he comes of a line of gentlemen, and a touch of scholarship won't hurt him when he sets out to peddle cloth. When it came to learning, Galileo was a startling revelation. He fairly soaked up Latin and Greek and philosophy and music and painting. Painting was his first love, and for a time he flirted with the idea of being an artist. Music was no trouble at all, and in a very short time old Vincenzio had to admit that the young Galileo could lute with the best of them.

Slowly it dawned upon Vincenzio that a boy of such talents would be wasted in the coat-and-suit field. Painting and music were out. There remained medicine. Doctors were flourishing fellows, and if they got jobs at the universities the pay was good. All right then, make a doctor out of Galileo. When this great question was settled the boy, seventeen years old, was

sent to the University of Pisa to study medicine under the great Andrea Cesalpino.

Galileo, being a perfectly dutiful son, set about listening to Cesalpino and making notes as carefully as the best of them. Old Vincenzio was delighted and gladly met the heavy burden his son's work at the university threw upon him. This expenditure, he thought, would all come back to him in fine fees when his son was a full-fledged doctor.

4

Here he is, then, eighteen years old, a tall boy awkwardly stumbling toward manhood, with a big head, buzzing with strange new thoughts. A boy with a seeing eye, that old inflammation that saved him from the church long since disappeared. Watch him, as he stands there in the Cathedral of Pisa. He is staring at a swinging lamp while the fingers of his right hand are clamped to the pulse in his left wrist. His lips move. He's counting.

For how many years have those lamps swung there? And how many hundreds of thousands have watched them, idly, and gone their way and never dreamed that they had been brushed by the wings of a great mystery?

To this counting boy of eighteen, those swinging lamps meant something, and out of his profound reverie he evolved the law of the pendulum and made possible the clock that stands on your shelf. The time of the swing, he found, using his own pulse as a clock to check his counting, remained constant regardless of the length of the oscillation.

This law he got at once, and using it as a basis he soon devised an instrument that made it possible for doctors to count the pulse accurately. No, the idea of making a clock did not come into his head. That's

fable. But when the right man came along—Huygens, say—Galileo's law went into the clock. And all of this made possible by an idle dreamer who stared at a swinging lamp while practical folk sniffed at him!

5

It wasn't long after that a great thing happened to Galileo—great for him, greater for the world. Among the friends of the Galilei family was a mathematician named Ricci—another to be made immortal by accident and association.

The Tuscan court, to which Ricci was attached, came to Pisa, and Galileo went to call on his friend. Just as Galileo reached the palace Ricci was giving the boys a lesson in geometry. Galileo stood outside the door and listened—and trembled. Here was a subject of which he was entirely ignorant, but something in him instantly jumped alive: he knew he must learn geometry. He was a dutiful son, and his father had said, "No mathematics, young man." But this had suddenly become a matter of vital importance. Ricci, listening to his pleadings, agreed to give him private lessons. In that moment Galileo became a mathematician, and his genius had come home.

There was storming on the part of Vincenzio when the secret leaked out. Mathematics was the worst-paid work in the world, even if he could get through school and find a place for himself. But this boy he had fathered would be himself, and nothing that could be said or done could make him over.

It was hard work killing that medical idea in Vincenzio. It died, however, before Galileo's advance. He swept through Euclid and Archimedes like a whirlwind. Old Vincenzio, himself a mathematician, knew a kindred spirit when he found one.

"Have it your own way, then," he grumbled at last. "Be a mathematician and a pauper—and be happy. I can't save you from your fate."

Neither could he keep his brilliant son any longer in school. The little money he had gave out, and in 1585 Galileo left the university without a degree. His parents were living in Florence, and he went to them, as yet, presumably, unfitted to cope with life.

Twenty-one years old he was, a sturdy, handsome, full-blooded young man. Time to play, time for sudden brawls and late hours and fierce flirtations. The hot blood of Italy was in him, and much might be forgiven his youth and spirits. But—there is nothing to forgive. Galileo had no energy to waste on such idle pursuits.

6

Almost at once, this boy who had finished no school, attracted attention with an essay describing a water-balance he had invented. He followed this with a paper on the center of gravity in solids. Light-hearted occupations for a youngster of twenty-one! Old Vincenzio shook his head and wondered when he heard his son called the "Archimedes of his time."

But Galileo won more than words of praise by these efforts. His reputation brought him the job of lecturer on mathematics at his old university at Pisa. The pay was even worse than Vincenzio had feared, but Galileo wasn't, at the moment, interested in money. There were a thousand things he wanted to do, and Pisa gave him a chance to do at least a few of them.

A dashing thinker, this Galileo, making bewildering short cuts to his conclusions. For instance: Aristotle said the speed of a falling body is in direct ration to its weight. That is, a body weighing ten pounds will fall ten times as fast as a body weighing one pound. This

on the face of it sounded reasonable, and everybody believed it was true; the professors at Pisa solemnly taught it to their students, and their students solemnly absorbed it. All but Galileo.

For some deep reason, this statement didn't make sense for him. He tried it out, experimenting in secret, and he found it was not true. Now Aristotle was only a degree or two lower than God to the scholars of that day. Seventeen centuries had fawned before the wisdom of the Greek sage, and Galileo was only twenty-five years old! Could he challenge such authority? But the bubbling confidence of youth had no understanding of the prejudice of age.

The leaning tower of Pisa made a fine field for his experiment. In some way he got the professors out to the tower. He showed them his one-hundred-pound weight and his one-pound weight. He told them what would happen if the two were dropped from the top of the tower at the same instant. Then he took his weights and started up the tower. There was chattering among the robed figures behind him.

"The boy's crazy, but let him have his way. This will teach him a lesson. How dare this whippersnapper disagree with the sublime Aristotle!"

There he was at the top. The leaning of the tower made a clear fall possible. He had the weights balanced on the edge.

"All clear below there. Here they come."

Down the weights crashed, the little fellow keeping up with the big one so that they struck the ground simultaneously. Did the bang of those falling bodies mark the destruction of Aristotle's throne? Ah, when a professor doesn't want to believe a thing, he won't see it or hear it or smell it!

Those who watched Galileo's experiment did not

want to believe, and they did not believe. They admitted that something had gone wrong in heaven or hell or earth, but they wouldn't admit Aristotle was wrong. They strongly suspected that Galileo had conjured the devil into the big weight for the purpose of checking its speed. They couldn't prove that he had done this, but it was altogether probable that something of that sort had happened.

Galileo had a sharp and a sarcastic tongue and he let it flay the academicians. That didn't make him any more popular.

7

Doubtless Galileo was inclined to be cocksure and intolerant of stupidity. These are faults natural to bright young people. Also, he had the disconcerting habit of telling the truth, regardless of policy. This was a trait worse than conceit, and it got him into his first serious trouble.

Giovanni de Medici, bastard son of Cosmo I, grand duke of Tuscany, looked upon himself as a mechanical genius, and in order to prove it he designed and built a big, expensive machine which was to be used to clean out the harbor of Leghorn. Galileo was asked for his opinion of this machine. He looked it over and then said it was no good and if they tried it they'd find it wouldn't work. At this Giovanni flew into a rage, which did not cool when the contraption, indeed, failed to work and turned out to be just as useless as Galileo had predicted.

Giovanni rushed to Cosmo and told his father what a snake in the grass Galileo was. Cosmo believed his son and turned a cold shoulder on Galileo. That made things fine for the professors, and they attacked Galileo

at every opportunity. The students took their cue from them and in turn laughed at him. They even became bold enough to hiss him in the lecture room—an insult that did not sit well with Galileo, who, beyond question, looked upon himself as a more than ordinarily clever young man.

In a fit of rage and wounded pride, he withdrew from the university, and returned to Florence.

8

Home again, this impassioned young priest of science was just in time to witness the death of Vincenzio. No more luting for him, no more worry over a son gone wrong in mathematics, no more scheming to get his hands on a few florins. No, this was the end for old Vincenzio, who had been burdened with a genius for a son.

Three sisters and a brother, all younger than himself, and no money and no position. That was the dismal situation that Galileo now faced. He was the head of the family, and his hands were empty. But Galileo was no weakling in the presence of adversity. Fortunately he had a friend who was rich and powerful and able to appreciate a scientist.

Marchese Guidubaldo del Monte of Pesaro had known Galileo and his work before the disastrous experience at Pisa. He guessed rightly that here was a boy who deserved help, and when in his distress Galileo appealed to him Guidubaldo used his influence to get a place for his young friend at Padua. Gladly Galileo accepted and signed up to lecture at the university for six years. His salary was equal to about $200 a year, which was just three times as much as he had received at Pisa.

9

However, the salary wasn't everything at Padua. Here was a real university. The mighty men of Italy had passed through these halls, and students flocked there in great numbers. Galileo knew that his chance had come and he made the most of it. He put every bit of his dynamic personality into his lectures, and they instantly became popular. Pupils eagerly went to him for additional instruction, and this work added considerably to his income. For them he wrote articles on the geometry of the sphere, on the lever, the pulley, the screw and on fortifications. It was in one of these papers that he first developed the principle that what is gained in power is lost in speed. This is basic in mechanics, and every man who shifts to low gear on a hill is making use of it.

During his first summer at Padua Galileo did a very peculiar thing, something that has never yet been rightly explained and which probably will forever remain a mystery. Here's the incident and see what you can make of it:

He and two other young men went out to a cavern near Padua and for some unknown reason decided to spend the night there. They elected to sleep at the entrance of the cave, out of which came a cool and probably poisonous draft. Within a day or two all three were taken sick. Galileo's two friends died, and he himself was never again well.

Now the question is: Why did Galileo pick that particular spot for a bed? He knew better, and likely enough his friends also knew better. Was it one of Galileo's inveterate experiments? It proved fatal to two and expensive and painful to the third. Anyway

there it is—incredible but well attested—and, as far as history tells us, the first of Galileo's follies.

## 10

Padua is not far from Venice, and Venice is a city of intrigue and passion. Moonlight and gondolas and deep shadows and general indifference to your neighbor's conduct make easy the paths of lovers.

Galileo, at any rate, found it that way. Where did he meet the mysterious woman who became his mistress? What is the truth of his romance and of his love-making? To what society did she belong? Was she dark and subtly smiling? Was she sparkling and vivacious? Where did she get the brains that made it possible for her to hold, for many years, the wisest man in the world? Was she some stately beauty, stepping out of character and class, to ally herself, illegitimately, with this fiercely loving professor and scientist?

"A lady of quality," one reads. This seems likely; the other kind would not have been apt to attract Galileo. What a difference here from the confiding Kepler, who told the wide world the story of his match-making! Galileo is silent as the grave; no eulogy and no complaint—suggesting a profound satisfaction.

Late in the nineties he set up a home for her, and she bore him three children, two daughters and a son. The boy was never much in the work of the world, and the girls became nuns. There was little else for them, springing as they did from so unusual a union. One of them, Celeste, we shall hear of again. In her burned something of her father's genius, tempered by the rigorous régime to which she submitted.

Galileo never married the mother of his children. When he left Padua she remained behind and a couple

of years later found a man who wished to marry her. Galileo had no objection; on the contrary, he gave her financial help which made her marriage possible—and thereafter she drops quietly out of the current of world-history.

One would like to know how she spent her time with this new husband. She had lain in the arms of an amazing genius, been fired by his enthusiasm and carried on the wings of his imagination. She had quieted him when he was disturbed, nursed him when he was sick, comforted his depression, shared his triumphs, wept at his failures. This world-figure had been her man.

Now she was mated to this quiet creature who took life as he found it, who did not bring her perplexing problems of an unheard of nature, nor irritate her with ideas too illusive, with dreams too subtle. Ah, well, by the exchange she gained at least repose and safety! But just the same one would like to know what went on in her head as she sat in the evening, looking at her husband and thinking of other days and other nights—and another man.

II

In 1599, Galileo was named as professor of mathematics at Padua for another six years. His salary was made about $350 a year. That was a fine rise and put him up in a class with the best-paid mathematicians in the country. His private pupils increased his income, and in addition he had opened a workshop where his inventions, now in demand, were manufactured. His water-balance, his sector, used in geometrical drawings, and his pendulum machine for counting the pulse were among the contrivances he manufactured.

All of this strengthened his financial status—which certainly needed help. He and his brother had gone

surety for his sister's dowry, and his brother turned out to be no help at all in meeting this debt. Still, from this time on, Galileo was never in want, although his obligations kept his nose pretty close to the grindstone.

Shortly after his reelection, tragedy brushed close to him. This is another event about which Galileo has remained, perhaps prudently, silent. But no silence can screen it, and the impression made upon his mind blazoned itself abroad in his conduct many years later.

## 12

This is what happened:

Giordano Bruno was as restless a soul as Galileo himself. He was sixteen years old when Galileo was born and was already a member of the order of Dominicans. He was a most impetuous monk, and it did not take him long to get into trouble with his brothers. He had his own ideas about transubstantiation and the immaculate conception—and his ideas weren't those of his superiors. This led to trouble and persecution, and Bruno fled.

He spent many years in France and at least two years in England, and he learned and taught much science. Very early he accepted the Copernican theory, and he advocated other notions frowned upon by Rome.

At last he wearied of his exile and went wandering back toward Italy. A friend invited him to Venice, assuring him, on bad authority, that he would be safe, forgotten by the Dominicans and ignored by Rome. This proved to be as completely wrong as a statement could be. The Dominicans were simply waiting, and Rome was still eager.

Almost immediately after his arrival in Venice, the agents of the Inquisition found him, arrested him, threw him into prison; and a little later Venice turned

her back upon her traditions of freedom, and surrendered Bruno to the mercies of Rome. He lingered seven years in prison, the seven years while Galileo was first lecturing at Padua, and tentatively advancing the Copernican theory.

In 1600, shortly after Galileo was elected for the second time at Padua, Bruno was taken out of his cell, released by the church to the secular arm, and burned at Rome on February 17.

13

All the essentials of Bruno's scientific teachings, Galileo believed. All the facts of Bruno's arrest and trial and death were familiar to him. Bruno's sturdy refusal to recant, his fierce clinging to the truth as he saw it, must have won Galileo's admiration while the penalty that was exacted planted deep in his mind a ghastly fear.

Years later this fear was to raise its head and betray a great man into a moment of weakness.

14

Check 1604 as a turning-point in Galileo's life, though the real bent of his genius did not become apparent until 1609. As in the cases of Brahe and Kepler, it was a new star that did it. Galileo gave three lectures upon this heavenly stranger. People were interested in the star and in Galileo, and at the first lecture the room was crowded to suffocation. The second address was given in a hall with seating capacity for a thousand. Even there the space was too limited, and the third talk was given outdoors.

Galileo was sharp with his hearers. He said they were numskulls to show so keen an interest in a mere novelty, while they were stone-deaf when one tried to

tell them about the marvels of the fixed stars or other important truths of nature. His audience took this good-naturedly, and everyone remained to hear what he had to say about the star.

What he said was plenty and as usual started a controversy. Aristotle, the benign and infallible Greek, had taught that the heavens were changeless and perfect. "That's a lot of bunk," Galileo shouted in good idiomatic Italian. "Here's a star, just like the other stars, that a little while ago wasn't, but which is now, though probably, it will shortly disappear again. Changeless? Nonsense. Nature doesn't know anything about permanence. And it's time you stopped mouthing Latin phrases, forgot Aristotle and paid some attention to the wonders and beauties around you."

You can imagine how the professorial fossils liked that!

They answered Galileo hotly. In the first place they were sore because the star had appeared. They couldn't do anything about that, however. But they would have been glad to ignore it, and they certainly thought the common people should not have been told of it. It was Galileo's public chatter that they objected to most strongly.

"All right," retorted Galileo, "if you are out to suppress part of the truth, I'll tell it all. Now just listen to this, and see how you like it."

What he told the public then was an account of the Copernican theory, and why he believed in it and why he was sure it was true.

There was rage in the professorial hearts at that. What! Dethrone the world? Tear it out of its position as the center of the universe? Make it a mere speck, a bit of dust flying around the sun? Sacrilege!

But Galileo stuck to Copernicus, and tried to think

up proofs, and kept on lecturing in Italian; and after a while the storm died down. The whole thing might have been forgotten if something very remarkable hadn't happened.

15

At Middleburg, in the Netherlands, lived a Dutch optician named Johannes Lippershey. A curious-minded fellow was this Hans. He'd rather play with lenses than make spectacles for aged clients in the accepted way. Fussing around, doing this and that, he found out, mostly by accident, that he could arrange two lenses in such a way that when he looked through them distant objects appeared near. This made a fascinating plaything. And as a matter of fact, Lippershey seems to have thought the contrivance merely an ingenious toy.

All of this happened in October, 1608. It was not until June of the next year that rumors of this toy reached Galileo. Note the difference between little Hans, the optician of Middleburg, and Galileo, the scientist. Hans had the telescope in his hands, and with it the wonders of the heavens could have been disclosed to him. But to Hans it was just a toy, fit only to fill an idle hour.

"A Dutchman has put two lenses together and objects seen through them appear quite near." That was all Galileo was told. Put yourself in his place. Nobody knew much about lenses except that they were good for bad eyes. How a lens should be made for a telescope, at what distance one lens should be from the other, whether a big lens was better than a small one, and in what kind of tube the lens should be enclosed, were undiscovered. No one had ever thought of asking these questions.

Lost in that sea of ignorance, could you make a telescope? Even with all you've read about telescopes, with the use you've made of opera-glasses and field-glasses, would you, right now, have the slightest idea how to go about making a telescope for yourself? Could you sit down in one night, figure it all out, and start the very next morning making a spyglass for yourself? That's exactly what Galileo did.

## 16

One long night of concentrated thought, of digging down for the principle of the thing, and Galileo was ready, the next morning, to make his first telescope. He took a piece of organ pipe; into one end he slipped a convex lens, and into the other end a concave lens—and there he had a spyglass capable of magnifying three times. It was a poor telescope, but it was a good deal better than anything Lippershey had made.

Hans stopped with a toy, but Galileo never stopped.

Instinct seems to have told Galileo that he was on the track of something big, and he instantly set about making another spyglass. This one magnified eight diameters; through it ships were seen at sea two hours before they were visible to the naked eye.

Galileo was vastly pleased with this instrument and, impetuous as a boy, rushed away to Venice to show it to the council and gloat over their words of amazement.

"Here," they cried, "is a miracle man." And they hinted that if Galileo wanted to give them the instrument they wouldn't refuse it. Galileo took the hint. It was a lucky move on his part, for instantly the council voted to double his salary at Padua and said the position was his for life.

17

Galileo ground more lenses, built more telescopes, making them better and better, and stronger and stronger, until at last he had one that would magnify thirty-two times. That's some jump from the first he built, the little thing of three diameters, which, at that, was better than anything Lippershey had turned out. No wonder most people think Galileo invented the telescope. At any rate, he took a toy and turned it into a mighty instrument of human progress.

One cloudless night at Padua the moon came up regally, and for the first time found herself looking down into a strange tube at the far end of which was a man's eye. That was a night in the history of the world! Old wives' tales went glimmering. The perfectly smooth silver surface of the moon proved to be rough and scarred and hewn into mighty mountains. Who could have dreamed that the moon would turn out to be such a worn old roué, upsetting the calculations of time's wisest men? The professors at Padua must have writhed that night. The moon's face not smooth and pure but torn and jagged as the old earth itself! And next came the statement that the earth shines exactly as the moon does, and "the old moon in the new moon's arms is due to the earth's shine hitting the unlighted part of the moon." Surely Aristotle turned in his grave when that statement was made.

18

There was more to come. The Milky Way, shimmering across the sky like the lacey draperies of a passing angel, is made up, Galileo announced, of individual stars. That star which twinkles above you is in reality

two stars. And all over the sky are scattered stars, too distant to be seen without the aid of this spyglass, the like of which there is not anywhere else in the world.

Aristotle's fine fancy of a perfect celestial dome was thus wiped out with one sweep of a poor, hastily built telescope.

But do you think the wise ones doing the teaching at Padua instantly believed all this? They might look through Galileo's telescope and see for themselves, but they would not. There probably was some trick here—and, anyway, if what Galileo saw was different from what Aristotle taught, Galileo was a liar and the whole thing was nothing but hocus-pocus, far beneath the dignity of a savant—too old to learn.

They grumbled, those old fellows to whom originality was a sin and experiment plain sacrilege. But in the meantime Galileo's telescope was pointed toward the heavens, and he continued his pioneer march through the stars. New things bobbed up constantly, and the sneers of the fossils grew bitterer, nastier. And then came the climax—the most sensational discovery of them all.

Galileo, after a few months' work, had grown expert with his spyglass. He was not to be fooled by snap observations and had learned to read aright the things that his glass showed him. But when, on January 8, 1610, he looked at Jupiter, he didn't believe his eyes. On the night before he had seen for the first time three little stars near Jupiter—two on the left and one on the right. But tonight all three were at the right. This was plain madness. Was his spyglass playing tricks on him?

The next night was cloudy, and Galileo cursed—and waited. January 10, clear, and Jupiter sailing plain

above him. But what could he make of this thing he now saw? There were only two stars and both at the left of Jupiter. The next night the two were still there in the same place, but one was now much larger than the other! On the very next night, there were four of these stars—three at the right and a big one at the left! And then Galileo knew he was not mad and his telescope did not lie. The explanation of the mystery came to him:

Jupiter had four moons as the earth had one.

19

Kepler, when he heard of this discovery, believed instantly—but Kepler was no humbug.

"I'm so far from disbelieving," he wrote Galileo, "that I long for a telescope to anticipate you, if possible, in discovering two around Mars, six or eight around Saturn, and one each around Mercury and Venus."

But Francesco Sizzi, Florentine astronomer and devout churchman, did not rival Kepler's enthusiasm. He went into communion with himself and evolved this masterly piece of reasoning:

"The satellites are invisible to the naked eye, and therefore can have no influence on the earth, and therefore would be useless, and therefore do not exist."

Galileo laughed at this, a little disgustedly, and he wrote Kepler:

"Oh, my dear Kepler, how I wish we could have one hearty laugh together! Here at Padua the principal professor of philosophy absolutely refuses to look through my telescope! And you should hear the professor of philosophy at Pisa laboring before the grand duke with logical arguments, as if with magical incantation, trying to charm the new planets out of the sky."

20

These moons of Jupiter, which created a sensation, raised Galileo to an exalted position, but in the end crushed him.

Venice was free and comparatively safe—in spite of the tragic fate of Bruno. Why then should Galileo want to return to Florence, which was neither free nor safe? He knew he had enemies, in the church and out —and he knew what the church could do. Bruno had been snatched from beneath his very eyes. Ah, well, Florence and Pisa were home, and he wanted to go back. He felt big enough to fight his enemies. No foe had ever triumphed over him. Who would dare to lay hands on the mighty Galileo, backed by dukes and safe in his honest belief in the creed of the church?

Gone were those years when the church could make a king stand barefoot in the snow and wait the pleasure of the pope.

Home to Florence. That's what Galileo schemed for and that's what he got. Tacitly, he was bound to Padua for life. But it was only a "gentlemen's agreement," and Galileo, throwing it over when Cosmo II made him a generous offer, instantly left Padua never to return.

That was his second great folly—and he paid for it in bitterness and pain.

21

Old Copernicus was no fool. A hundred years before Galileo turned his spyglass toward the stars, the priest had predicted that, if the human eye were ever keen enough, it would see that Venus and Mercury had phases like the moon. Galileo's glass proved Copernicus was right about Venus.

That one caught the professors who still taught Ptolemy. They were left without a leg to stand on and could cling to Ptolemy only through their own stubbornness. And the end, for them, was not yet.

"Let's take a look at the sun," said Galileo. "Everything in the heavens is different from what we expected. Maybe the sun, also, is different."

He looked. On the face of the sun he saw—spots! Impossible! No one had ever dreamed so wild a thing. Impossible, if you like but there the spots were. And what was this? They moved, they changed—no. It was not they which moved: the sun itself was revolving on its axis!

But Galileo wasted no time on the clamor and wailing around the bier of Aristotle, the fallen god. He was living at the end of his telescope, pointed now at Saturn. This planet is triple, he wrote Kepler. But was it? He could never be quite sure about that. And now when he went back to it, two stars had vanished. That was a shock. Had his spyglass fooled him? Or, remembering the old Greek legend, had Saturn devoured his children? If so, he might spew them out again. They'll reappear, said Galileo. They did. Galileo's glass was too weak to tell him the truth about the rings of Saturn, but he knew he had seen something, and he believed what he saw.

22

As a result of these discoveries enemies multiplied around this rebel and his spyglass. Devotees of the church raised their hands in horror. This spying creature must not be allowed to rob the common people of their religion and of their God. They put their heads together and planned to quiet Galileo.

It was not easy. The man they attacked lived in the

white light of fame. And he was a devout Catholic. But, as the fury of their onslaught increased, it occurred to Galileo that it might be a good idea to go to Rome, make his position clear, get everything smoothed out, secure his safety.

Galileo in Rome was fêted, made much of, honored by church and state. But—a fly slipped into the ointment. Copernicus's book was banned, and Galileo was put on his honor not again to teach the silly notion, obviously contrary to the Bible, that the earth revolves around the sun.

Galileo agreed, thinking the whole thing, as far as he was concerned, a mere formality. But he put a weapon into the hands of his enemies. Better for him had he stayed away from Rome—and missed these empty honors. Better still had he stuck to the letter of his agreement and remained at Padua.

23

That first visit to Rome, attended with fêtes and honors—and the pope's finger uplifted in serious warning—was in 1615. Copernicus's book was banned, and Galileo was gagged. Not for more than two hundred years did the church lift that ban. Quietly, in 1885, 7
the chains were struck from Copernicus—and much good it did him.

Nine years slipped away. Galileo was busy; his enemies were busy—watchful to spy out heresy, God being in His own right powerless to defend Himself, leaning, it appears, on these lynx-eyed ones.

Galileo was quiet; his watchers, noisy with words, fretted and snarled at a safe distance from the star-gazer. Quietly busy all these years, this man marked for destruction. Illness, with shooting rheumatic pains, traced back to that night spent at the mouth of the cave,

afflicted the aging scientist. When well, he did small things, tinkered the convent clock that had refused to go; carried presents to the lady superior, in whose hands were now his two daughters; pondered hydrostatics, and swept the friendly sky with his spyglass.

Galileo was getting on. Three-score years of struggle and victory had passed. Fame could give him nothing more, and the fight with poverty was forgotten. But the truth, as it came pouring into his head, must be told to the world. If one only dared ignore that papal warning—

But time sets matters right. The pope who warned died. Urban VIII now reigned, and Urban was that same Cardinal Barberini, a "man of considerable enlightenment," who was Galileo's friend. Urban would listen—within reason; and would let him expound his views—within reason. So Galileo supposed.

He could let all men know what he thought. Only for safety's sake he strove to do it by indirection. He wrote and published "Dialogues on the Ptolemaic and Copernican Systems." This was his scheme for indirection. Not an opinion of Galileo's, in his own person, appears in the book, and no conclusion as to the relative merits of the two systems is arrived at. As further caution, he tacked on a preface in which he says the Copernican system is presented purely as an hypothesis and is not at all to be taken seriously or as a fact.

So, hedged about by guards and protected by a friendly pope, book and author might thrive.

24

Never would sly lynx-eyes miss so fine a chance. The warning issued in 1616 still stood. Here was direct violation of the church's mandate, of Galileo's prom-

ise. But, more and worse, Galileo's enemies declare that Simplicio—who in the book defends Aristotle and at whom Galileo constantly pokes fun—is the living image of Pope Urban. Surely his Holiness had but to glance at it to see that in this book his undutiful son, Galileo, had held him up to ridicule. Urban looked, and pricked vanity raised a suspicion that swarmed toward certainty.

Galileo was ordered to Rome.

In the writing of the book, in the getting it published, nine years had passed. Galileo was seventy—and not well. That was a dread summons! Many in the past had heard it, had gone to the Holy City and never returned. At his side as he went toward Rome moved the shade of Savonarola, of John Huss, of Bruno.

25

No fêtes and honors for him this time; only chilling commands to remain indoors, to seclude himself, to await the call of the Inquisition. In the hands of that frightful tribunal, he is taken to its chambers, examined and again examined—asked questions by men set to turn his words against him.

There was never a doubt of his guilt. His offense rang in the ears of all fearful Christians. The Inquisition did not sit to establish his guilt. Not for that were the questions hurled at him; not for that was he led into the torture room that he might see with his own eyes the cruel instruments designed to purify the souls of heretics. The guilt was plain. These measures were to force him to recant, to abjure his hellish heresy.

Those of his friends who were permitted to see him begged him, weeping, to recant. From Arcetri, his daughter Sister Maria Celeste, wrote him piteous tear-

stained letters. Save yourself, Galileo. Recant, recant. So his friends hurled their appeals at him. And Galileo would not recant. One imagines one hears, through the centuries, Galileo saying:

"Am I not a Christian? Am I not a proud son of the church? Am I not kneeling in the dust and adoring God, the Father Almighty, and Jesus Christ, his Son? Recant? What shall I recant? Shall I hide the truth and by so doing throw lies into the face of the church and damn my soul with blasphemy? Oh, my friends, I who have told the truth, shall I now abjure my faith and call God a liar?"

26

There were five stages in a rigorous examination under the careful rules of the Inquisition. First, the official threat of torture was made in the courtroom. Next, the offender was taken to the door of the torture chamber and the threat was renewed. Third, the heretic was taken inside the chamber, and the instruments of torture were shown to him. Fourth, the victim was undressed and bound upon the rack. Fifth, the torture was applied. After each stage the accused was given an opportunity to recant.

It was in February that Galileo arrived in Rome. He was examined many times, and in the course of these examinations days and weeks passed. And Galileo remained firm not to recant. So spring breathed into summer, and the twenty-first of June dawned. Out in the gardens of Rome day was bright and warm. To Galileo it was dark, and there was a whispering of pain and of death in the small wind.

For on this day he was summoned to the Inquisition for rigorous examination. Quietly he repaired to the chamber of horrors, leaving behind him his pleading,

weeping friends. The door opened, closed, and there came out to the anxious ones no word of how things went with the vanished master.

That was a long day, longest of the year. But the next day was longer, and the lagging minutes brought no tidings. Another night and another awful day sinking by long seconds into another frightful night.

On the twenty-fourth of June Galileo came back to his friends.

27

Five stages in the "rigorous examination." Through how many of them did Galileo pass? The archives give no answer to that question. Did Galileo ever whisper to his friends the details of that examination? Probably not. Somewhere along the line his spirit broke. At some point he cried out:

"Enough. I recant. I abjure. I curse my heresy. What more can I do?"

"Sign," said the ten cardinals.

Galileo signed.

Not for him, when he rose from his knees, broken and shaken with horror, was there any thought of the earth and its movements. In that moment he was not a scientist and an explorer. He was only an old man, sick and frightened and longing, before all else, for the feel of his daughter's arms, for the sound of his friends' voices.

28

Galileo was a prisoner. He was not shut in one of the Inquisition's dungeons, but he was deprived of liberty. For a few days he was kept near Rome and then was removed to Siena and put in charge of the Archbishop Piccolomini. There, cut off from the

world, he remained for six months. In the following December, the church grew kind, and Galileo was permitted to go to his old home at Arcetri, near Florence. However, he was warned that he must remain at Arcetri and under no circumstances go into Florence. Friends could visit him, but there must be only two or three at a time.

During his stay at Siena, Galileo had longed often for the comfort of his daughter Maria Celeste. At Arcetri she would be near him, able to help in the hard task of again picking up the threads of his life. At Siena he dreamed of the many little things she would do for him. She had watched over his property during his long absence. She had suffered as the trial dragged on, worried over his illness, agonized during the three days of his final examination. And her letters had been the only bright spots in Galileo's darkness.

At Arcetri he found her again only to lose her. Grief and worry had sapped her strength. Even before he left Siena, the girl had felt that her time was short, and early in December she wrote:

"I do not think I shall live to see the hour of your return. Yet may God grant it if it be for the best."

It turned out to be for the best, and they were reunited but there could have been little joy for Galileo in that reunion. Celeste was sick. All through the winter months she grew worse, became critically ill late in March, and on April 2, 1634, she died.

29

Habits more than fifty years old now saved Galileo. From his earliest years he had worked, and in spite of physical and mental pain he must go on working. In that way he could climb over his grief and forget that he was still a prisoner.

"My restless brain goes grinding on," he wrote seven months after his daughter's death—grinding, this time, the "Dialogue on the New Sciences." This was a work he wanted done before the last call came; and he was not sure there was time to finish it.

These "new sciences" were mechanics. For many years Galileo had studied the forces at work in everyday life. Thus as we saw he had touched hydrostatics, the law of falling bodies, the gain of power and the loss of speed. Now the time had come to go farther; and he wrote at length in these dialogues of cohesion, of resistance to fracture, and of motion, uniform, accelerated, and projectile. In these dialogues he laid down the facts that were later, by Newton, to be developed as the three laws of motion—and so to become part of the common knowledge of all men. These laws, thus sired by Galileo in his old age, are:

1st. If no force acts on a body it will continue to move uniformly both in speed and direction.

2nd. When a force acts, the motion changes either in speed or direction or both, at a pace proportional to the magnitude of the force, and in the same direction as that in which the force acts.

3rd. The centrifugal force and the centripetal force are equal and together constitute the tension in the elastic.

These are the laws of motion worded by Isaac Newton but based on Galileo's work. The dress is Newton's, but the body is Galileo's.

"Dynamics is the science of forces accelerated or retarded," wrote the great Italian mathematician Lagrange. "And Galileo laid the foundations of this science. His work in mechanics forms the most solid and the most real part of the glory of this great man."

Galileo himself called his work in mechanics a new

science, invented by him from its very first principles. As he was thoroughly acquainted with the writings of Archimedes, there probably was a bit of swagger in this statement, but it is true that mechanics, as a modern science, received its impetus and its direction from the powerful, probing mind of Galileo.

30

These dialogues were finished by 1636. It is well they were. The light was going out—literally. In the summer of that year, Galileo's sight began to fail and in less than a year he was blind in the right eye while the vision of the left was greatly obscured. By December, 1637, he was totally blind. On the second of January, 1638, he wrote to a friend:

"Alas, reverend sir, Galileo, your devoted friend and servant, has been for a month incurably blind. This heaven, this earth, this universe, which I by my observations have enlarged a thousandfold, are now shriveled up for me into that narrow compass that is occupied by my own person."

This was hardly the strict truth, for his mind was "ceaselessly grinding," and his keen memory brought back to him the visions of other days. Even with his eyesight gone, problems in mechanics still teased him. Thus one of his last efforts was to apply the pendulum to the measurement of time. How long had this idea lain in his mind? Did it date back to that youthful morning in the cathedral of Pisa? Hardly. At any rate, after more than half a century, it bobs up, occupies him in his moments of blindness, and gives further proof of his startling genius. The days, however, were running swiftly out, and this problem he was not to finish.

31

In spite of his afflictions, the Inquisition still held Galileo. True, the restraint was relaxed, but it was never entirely taken away. In the summer of 1638 he was permitted to go to Florence to live with his son; but the number of callers was still limited, and he was forbidden to leave the city.

It was during that summer that he received a strange visitor. It was a sad but dramatic meeting when the young John Milton, full of Puritanical fire, stood gazing with flashing brown eyes at the tottering blind giant. Little record of this moment now exists. Milton refers to it briefly:

"There it was that I found and visited the famous Galileo, grown old, a prisoner to the Inquisition for thinking in astronomy otherwise than the Franciscan and Dominican licensers thought."

That's all. No mention of blindness, no hint of prophetic angels, no quoting of words of wisdom that passed from one to the other. But we may be sure that more than once, in after years, the memory of that scene in Florence came back to the brooding, sightless John Milton.

32

Waiting is a long time, and a "grinding" brain is bad company for a bedridden old man. Dead was the daughter who should have soothed these painful days. Gone was the woman who had mothered that daughter. Gone were old friends, though a new and dear one, the young genius, Viviani, was at hand, driven by love and veneration to serve the dying master.

It was on the fifth of November that Galileo went

to bed never again to rise. He burned with fever, he was maddened by sleeplessness, he was smothered with palpitations, and racked with the pains of an old hernia, but his mind was clear. With Viviani he discussed scientific problems and planned a treatise on the movements of animals and dictated notes for a dialogue on percussion. So many problems and so little time left!

On the eighth of January, 1642, there was a stir and a panic hurrying in the little home at Arcetri. A quick call for the last rites and sacrament—extreme unction. "Into thy hands, oh Lord, we commend his soul." The short winter day closes swiftly toward the night.

Seventy-eight years have come and gone since the birth of this man at Pisa. He has ridden on the crest of fame. He built himself a magic eye to see beyond the limits of the universe. He moved arrogantly, scorning the ways of little men and these turned and snapped at him; they snarled themselves into a pack and dragged him down, cast him into prison. Now for all the rest of their narrow lives they can snap and snarl as they please. Their victim has escaped. Galileo is free. . . .

*Chapter Eighteen*

# ISAAC NEWTON

THERE was hurrying and scurrying in the manor-house of Woolsthorpe on Christmas Day, 1642. In one room lay a woman, white and wasted, while on a pillow near her rested a three-pound baby—alive, but trembling toward death. Frightened old midwives went hurriedly to Colsterworth for the doctor, for medicine.

On the way they grumbled to each other: "What fools to run ourselves to death! The baby's as good as dead. It's a miracle if he lives until we get back. Such a tiny mite, he is. And we old women run our legs off, and he'll die anyway and no thanks we will get. It's a hard trade, sister, the good Lord has found for us. Thank heavens, here we are at last."

They rushed back to Woolsthorpe, where a giant among men, weight three pounds, lay fighting for breath. What were the aching lungs and aching legs of two old midwives when the life of such a baby hung in the balance? You two poor old women, cursing your hard necessity, who are you? Nameless shadows that dive into the pages of history for a fleeting second—and then are lost.

But, for once your work is well done. The baby will live.

2

So Isaac Newton lived, and his mother lived, and that mad anxious Christmas Day of the year 1642 was

almost forgotten, and life at Woolsthorpe settled down into the ordinary run of things.

Little Isaac picked up weight, and his mother grew stronger. His father had died some weeks, or even months before Isaac was born. He had been a farmer, owning his own place, a small farm that had been in the family for a hundred years. He had picked a living out of his land by hard work and endless thrift. He died almost three hundred years ago, and history was not then interested in that small farmer at Woolsthrope.

History knows almost nothing about him. One can imagine him sturdy and self-reliant, with a good head, with honest eyes looking out straight at the commonplace things about him.

In this straight way of his, he saw near at hand, Hannah Ayscough, and his fancy settled on her. They were married, and soon after something struck him down, pneumonia or a breath of the pestilence that was forever sweeping out of Europe. Hannah was thus left a widow while she was still a bride. If crushed by this tragic interruption to her honeymoon, at any rate, she was not beaten since she carried on, gave birth to a son, recovered, and in time was spoken of as "an extraordinarily good woman."

Two years after Isaac's birth, Hannah married the Rev. Mr. Barnabas Smith and went to live at North Witham.

The rector apparently had no liking for a ready-made family, so Isaac was left with his grandmother. Hannah presented Smith with three children of his own, two girls and a boy. Then Smith was gathered to his fathers, and Hannah came back to Woolsthorpe.

3

Isaac was fourteen when his mother returned. He had gone to school at Skillington and Stokes and then to the grammar school at Grantham, boarding with the village druggist, who thus creeps out of obscurity under the name of Clark—and will live forever because he once gave room and board to a schoolboy!

Not a bright boy, this young Newton, but meditative and aloof. Because he was shy and slow to take part in boyish games, the other youngsters picked on him, bullied him. But even a shy boy will turn if crowded too far. Isaac turned, one day, to the amazement of everyone, and flew into the school bully, reckless of any injury to himself, maddened by a just rage, and beat with his small fists and clawed and wept and won a slightly sanguinary victory. History sets it down as his only battle, and paints him as ever after a quiet man of peace.

Did this fight stir hitherto sluggish glands? Did the anger-released adrenalin set things humping inside him? Figure it as you please, but from that day Isaac was a changed boy. Ways that had been dark turned bright, and he rapidly crowded ahead in his school work, became, if not exactly brilliant, at least superior to his fellows.

Then his twice-widowed mother came home with her three children and no money—none to speak of; maybe a total of about $400 a year—and five of them to take care of with that sum! As the wife of a rector, an educated man, life hadn't been easy for Hannah. Doubtless she came of a line of farmers, so farming was to her, a safe and sane way of living. Naturally it followed that Isaac should be a farmer.

So home from Grantham came Isaac, aged fourteen and a half, to be turned into a farmer at his mother's command. Old King Canute had an easier job when he tackled the tides—with little recorded success.

4

Being dutiful, Isaac tried to be an honest tiller of the soil. But it's hard to dig successfully when your head is full of strange dreams. And hard on market days at Grantham, to haggle over prices, when at the druggist's home there were books waiting to be read. So he borrowed the books and, while an old servant jogged into Grantham, a boy lay under a hedge and read to his heart's content. But such vicarious trading seldom nets big profits. It did not so with Newton.

His mother probably blustered and scolded, but it's not easy to be severe with a boy who always means to do the right thing—if only the dreams will keep away! Dreams he had of mechanical contrivances, mostly. The water-clocks he built, the sun-dials he set up, the perfectly flying kites he made, the sunlight that fascinated him, all the subtle ways of Nature that a boy could see and ponder and not understand—these were the dreams born in this boy's head.

There was the wind, for instance. Mark this strange juxtaposition of fates: On the third of September, 1658, Oliver Cromwell lay dying in London. He moaned and sighed, speaking often of God, to whose feet he was slowly creeping. His last words were scarcely audible to his sorrowing friends, for outside a great storm raged. And at that hour, at Woolsthorpe, in the county of Lincoln, young Isaac Newton was out in the storm, uniquely studying the force of the wind. Jump with it, jump against it; what is the dif-

ference in distance? Compute, then, the power of the wind. What a problem for a boy, sixteen, and ignorant of mathematics! Was this the stuff out of which to make a farmer?

5

This boy, in spite of himself, will go his own way. Hannah complained to her brother, rector at Burton Coggles, but she got no sympathy there, or, at best, sympathy with advice that shattered her plans. "Face your poverty; doubtless the Lord will provide." At any rate, Isaac was sent back to school. Creditable advance in his work soon sent him to Trinity College, Cambridge, where he dipped into things hitherto hidden from him. Among them Euclid. Little if any geometry had come his way thus far, but he found the problems set down by the old Greek so nearly self-evident and so easy that he threw the book away with the words, "This is all trivial."

Once more his school work was interrupted. Over in London, that hideous cesspool of the seventeenth century, the plague raged and, as it reached its murderous fingers into the country, schools were closed and students fled. That's how it happened that Newton went back to Woolsthorpe—but not to farm.

Light always fascinated this boy, and the fascination still held. On this plague-caused vacation he began working with prisms in an effort to learn something about sunlight. Later these studies were to break light into its various colored rays and lay the foundation of the whole modern theory. He was the first to split the "white light of infinity" and mark down the varying degrees of refrangibility for the rays of each color.

Those who now seek the health-giving violet ray owe

a debt to Newton, who arranged his prisms this way and that, in the path of a single ray of sunlight admitted through a hole in the shutter of his Woolsthorpe window. What matter if his theory of particles in light did go wrong? Huygens was at hand to talk of waves and set the world on the right track.

6

Also at this time there bobs up evidence of Isaac's interest in gravitation. Don't make the mistake of thinking that Newton reached out and picked this theory out of the blue. And you needn't place too much dependence on the apple story. Take it as a symbol. Certainly the apple fell, and it may even have cracked Isaac on the head.

And at that he would have remembered the work of Kepler and the work of Galileo. He would have looked at the sun and considered the moon and the stars and the earth on which he sat, whirling through space at the rate of sixty thousand miles an hour. A reasonable train of thought, following that thump on the head? Would your brain have moved like that? The lead that would solve the mystery of the radio or chart the path of storms ten years in advance may be right now just as close to you as Newton's apple was to him. Or the cause of death. Just as common an occurrence as the fall of an apple. The line is there, the data are spread before us—more than Newton had for his gravitation—but where is the solution? Or of old age? Plenty of problems for the wise ones who think the masters had an easy time of it.

Anyway, Englishmen cling to the apple story. Even the tree from which it fell could, until recently, be pointed out to the curious. When it crashed, it was cut up into mementos that are still preserved.

## 7

No one knows for how long Newton had dreamed of gravity. Country boys make slings out of which, by whirling, they throw stones. They are also given to swinging a pail of milk over their heads. Sometimes the milk doesn't spill. A grinning trick—if everything works right. Also there were those kites that had pulled at the string in his hand, and many other trifling incidents that you and I would miss entirely.

These, or something, set him asking, "What is the force that holds the stone in the sling, the milk in the pail?"

There was a constant pull and a constant effort to escape that pull; two forces acting against each other, balancing each other. He was on this line six years before Huygens published the laws of centrifugal force. In some way Newton sensed the whole theory, and he at once set about trying to prove it with hard mathematics.

Quite naturally he chose the moon to work with. The moon he thought of as the stone in the sling and the earth as the boy's hand; gravity was the invisible string. So he figured it all out—and he was wrong. It wouldn't work. On the basis of his calculations the moon wouldn't be where it is—and that was that. No use then. Throw the whole thing away.

That was a bitter blow. Isaac thought he had his finger on the pulse of the universe and was pushing toward a great discovery, and here he found it was all as silly as any hypothesis with which Kepler had fooled himself.

So this twenty-three-year-old philosopher, as he says, "laid aside at that time further thought of the matter."

8

If gravity won't work, he thought, and the most stupendous secret in the universe is withheld from us, let's try something easier, something we can get our hands on. There's the telescope, for instance. The image in the object glass is blurred. And why not, since the rays of various colors in the light are not refracted in the same degree? We have proved that with our prisms and the sunlight through the shutter. Others have blamed this blurring on imperfect lenses. That's wrong. No perfection of lens will change the nature of light. How to get around this difficulty, then? Why not a reflecting telescope? A concave mirror would form an image and do away with the refraction.

Instantly he set about making his telescope with the image thrown on a mirror. It worked. The instrument was only one inch in diameter, and six inches long, but it magnified forty times and gave a good view of Jupiter's moons. An ordinary telescope four feet long was no better than this midget of Newton's.

This success drove him to try again. He made a larger one, and when it was finished it was the best telescope in the world. You can see it, if you like, in the library of the Royal Society—at London, and there you can read: "The first reflecting telescope, invented by Sir Isaac Newton, and made with his own hands."

If you get a chance at any of the enormous telescopes now in use, you will find they are reflecting instruments, basically exactly like the one Newton made over two hundred and fifty years ago.

9

When the plague disappeared and Newton returned to Cambridge, he was not yet twenty-five years old, but

he had laid the foundation for every bit of the work that has made him immortal. He had invented Fluxions, that is, differential calculus; he had formulated, without as yet being able to prove, the law of universal gravity; he had given clear expression to Galileo's three laws of motion; he had analyzed sunlight and made possible spectrum analysis. He had not yet finished school, and he had published nothing. It was not until the next year, 1668, that he got his A.B. In private circles he was known as a mathematician of great ability, but the public had never heard of him.

His mathematical ability secured for him, in 1669, the Lucasion chair of mathematics at Cambridge, and he settled down to lecture and study as a quiet, unobtrusive professor. It is not on record that his lectures were especially exciting or that personally he was more than ordinarily popular. The lightning speed with which he solved the most difficult problems must have been disconcerting even to his admirers.

He was unprepossessing in appearance, and his habits were not likely to arouse envy. Of medium height, he was inclined to be heavy. He had a finely shaped head with abundant hair, which later in life was snow-white. His eyes were dark and lively, though in general there was little show of animation about him. He had no flashes of wit, and his conversation was solid.

At no time does one feel any youth in this man. Here was none of the romantic boyishness of Kepler, the theatrical dash of Galileo. Yet he was no plodder. His glance, swift as lightning, saw to the bottom of every problem, and the movements of his mind were too rapid for the ordinary person to follow.

Concentration shut him off from the world, made him indifferent to others, indifferent to himself. He

never bothered his head about dress. His stockings could and did drag around his heels, and he wouldn't notice or care. If he were going out to dinner, someone had to fix him up. Otherwise he'd go just as he happened to be and most likely he'd be far from presentable.

If he were dining at home, he had to be dragged to the table and almost forcibly fed. If he had company and left the room to get a bottle of wine, there was a fair chance that he'd forget to come back. He was proverbially absent-minded, and stories grew around his name—largely fiction. There was one of his leading a horse up-hill. At the summit he turned to mount, only to find the horse gone though he carried the bridle in his hand. Another story is of a friend invited to dinner. Food was put on the table, but Isaac didn't appear. The friend helped himself to roast chicken, ate it all, and put the bones back in the dish. Newton came in, and, seeing the bones, said, "Ah, I thought I hadn't dined, but I see I have."

The truth of these stories is of no importance. They show he was dreamy, untidy, and modest. No self-seeker, here, but a deep thinker, feeling his way where planets whirled and universes were born and died.

10

After this, it seems needless to add he was a bachelor. Yet there had been a time—

In that summer when he was home to escape the plague he was twenty-three years old and strong and well—a healthy young animal. And there were cousins, daughters of that uncle who had helped save him from the farm. He spent much of his time at the rector's home. Even to a student, busy inventing differential calculus, propinquity means something.

There were long talks, and the fair cousin listened, absorbed, to an endless monologue that was all just so many words to her. Girls will do that sort of thing, even now. She was so violently interested, that Newton's ego stirred.

"Surely," he thought, "I must be a devil of a fellow if this charming girl finds so fascinating everything I say. And she, of course, is a very unusual person with a marvelous brain. What a comfort to have her help me solve my hard problems—another brain working at my side."

So men have dreamed about women since the world began.

But what happened? Did the strain of listening to talk she could never understand prove too great for the cousin? Did a dashing young numskull, full of chatter, come along and carry her away? Did Isaac, in his poverty, seem a bad match? Did she decide that, in spite of long talks that didn't seem to make sense, he was a stupid fellow who would never amount to anything? Or did Isaac, absent-mindedly, forget to propose? That wouldn't have saved him in our age.

Whatever the reason, they separated. She married another, and long afterwards she and Newton were friends, youth's fires burned out, so he could help her with cash when the times were hard and probably never remember that at one time this woman had roused strange emotions in his breast. That is all there is of so-called romance in the life of Isaac Newton.

II

Now gravity bobbed up again in Newton's life. Over in France a scientist named Picard had been making careful measurements to determine the length of a degree on the surface of the earth. The old reckoning

gave a degree sixty and a fraction miles. Picard found it was nearer seventy miles—sixty-nine and a fraction.

When Isaac had first attacked the problem of the moon and gravity he knew that, if his theory was right, the moon should fall toward the earth sixteen feet every minute. His first calculation, back there when he was a boy of twenty-three, had shown that it fell only thirteen and a fraction. It was this that made him lay aside the theory and "think no more about it."

But now in 1672 came word that his original data had been wrong. The size of the earth was greater than he had thought. Could it be possible that this new, accurate measurement would bring the thing out right? Would it prove, after all, that his theory was sound? Those extra miles would make a difference. Would it be enough? If only it should fit perfectly!

He trembled with excitement as his fingers dashed down the figures with pencil and paper. This man, stolid and heavy and without youth, as he hung over that paper, with flushed cheeks and flashing eyes, became the very embodiment of youth. Faster than his fingers could fly, traveled that brain of his. He swept ahead toward the conclusion. Yes, yes, yes! He threw down the pencil. It was needless to continue the work. He has won the secret of the universe, and stands now with Kepler and Galileo—the trio that has forced the sun and stars to tell their story.

12

What really had Newton done when he threw down that pencil on an unfinished problem? Discovered gravity? Only the more than usually stupid say that. Gravity was discovered by the first man who fell out of a tree. Everyone knew, had always known, that there was something that pulled things toward the center of

the earth. Kepler had been right on the heels of Newton's problem when he talked about the moon piling up the tides. Galileo, with his falling bodies and his study of projectiles, dragged out of nature the three governing laws. But there he stopped. Newton made the application.

Many, many centuries ago men fabled that the world was held in place by a giant who stood on the back of a bull that stood on a turtle. Down into the middle ages, most people, counting by noses, thought the world was flat and there were pillars at the four corners holding it up. Upon what did the supporting pillars rest? That wasn't any of their business. This idea waned slowly, and after the voyages of discovery proved the earth round, it was accepted as self-supporting and stationary at the center of things. Long ago an old Norse had said the world was round and a serpent circling it held his tail in his mouth and supported it.

Kepler recognized gravity, and he charted the orbits of the planets and worked out the laws of their motion. But he never tackled the problem of why each planet stuck to its particular orbit and why it kept on whizzing. Galileo's three laws of mechanics and Kepler's three laws of celestial motion were the tools put in Newton's hands for use in proving his theory. But he voiced the theory and demonstrated its truth.

Since Newton's time a legend has been only a legend. Even those people who haven't the least idea what is meant by universal gravity don't believe a giant holds the earth on the back of his neck.

What is this power that juggles worlds as one juggles pebbles? that swings the sun and the solar system forward at the rate of twelve miles a second? How does it reach out and with invisible lines clamp planet to

sun, and sun, perhaps, to some mightier and distant sun? None of these questions Newton answered. None of these questions has any man answered.

13

Isaac Newton, when success smiled on him, did not break into hurrahs and print. What he did was to spend two more years thinking about, and working at, his big task. Two years, living in a thick haze of figures. Not a word to anyone; just going ahead, grappling with one planet after another, seeing his theory prove itself, no matter to what part of the universe he applied it.

And when it was done, when the first part of his great work, "Principia," was finished, he did not then turn it over to a printer. He didn't even mention it to the Royal Society. He put it away in his trunk and went about his ordinary business. He did this because his paper on optics had got him into a dispute with other scientists, and he wished not to have a fuss over his gravity idea. As far as he was concerned the job was done, and that's all there was to it.

But a work of this sort isn't born to die in a philosopher's trunk. Edmund Halley became the god of the machine. Halley had a problem that no one in England had been able to solve. He wanted proof that the path of a planet, subject to an inverse square law, would be an ellipse. Naturally he appealed to Newton. Now this was exactly what Newton had spent two years proving to his own satisfaction. In answer to Halley he was able to say at once:

"Why, I have calculated that."

So he had. And with some delay, due to Newton's reluctance to get into print, "Principia" was put in Halley's hands. But Halley's troubles were not over.

He showed the book to the Royal Society, and the Royal Society was going to publish it; then it changed its mind and decided it was too hard-up to do so. At last there was nothing for it. Halley had to publish it at his own expense.

The book created a sensation, Halley got his money back—and the Royal Society looked decidedly foolish.

14

Naturally the word-war that Newton dreaded developed. Hooke, who was himself a shark at mathematics, claimed the theory as his own and tried to get the Royal Society to back his claim. Actually he had worked on the problem, but he had not as yet proved it and there's some doubt if he had really formulated the theory as Newton understood and expressed it. At any rate, the two authorities got together after some wrangling, and in the second edition Newton gave Hooke all the credit he was entitled to, or more.

Newton at this time was forty-five years old, and with the exception of preparing a book on his differential calculus his work was complete. The strange thing about this man Newton is that his work, as we said, was all but done at the age of twenty-three. Had he known then the real size of the earth, his calculations on gravity would have come out right. That is to say, his theory was perfect and lacked only accurate data to demonstrate it.

He had given the world an embracing law of the universe and had thus exposed much fable and legend and folklore as superstition.

He had broken white light and showed its nature, and framed the laws of refrangibility.

He had built a reflecting telescope and enormously widened the visible universe.

He had invented differential calculus—and the average college boy will give him no thanks for that.

15

Forty-five and everything done? That's a strange record. Was he burned out? Was his imagination too limited to suggest new problems? Had his hard, ceaseless work worn down his resiliency? Was he at forty-five just a hollow shell?

He was elected to parliament—and did nothing while there. Again running for election, he was overwhelmingly defeated. And at that time he was one of the most famous men in the world.

Oliver Cromwell and Richard Cromwell and Charles II had come and gone during his lifetime. James II came in blustering and left hurriedly. Mary and William III reigned. Piping times for old England, for liberty, for all men. But he was at no time part of this tumult. Storms raged around him, but he was removed to the center of a philosophic calm. Archimedes acted differently.

The evidence points that there was a period when his mind failed. His dog Diamond tipped over a candle in Isaac's room, and papers and notes of twenty years' accumulation were burned. It seemed to him a frightful accident, a calamity. He made little complaint, but he brooded and fell into an alarming melancholy. Yet, so far as the world knows, nothing of rare value was lost. He had no heart-breaking calculations to do over. Everything was done and published. But there may have been something—

Some of the letters he wrote not long after this still make strange reading. One to Samuel Pepys is illogical,

not the product of a sound mind. But the attack was temporary. He recovered and went about his business with all his old assurance.

Then someone called the attention of Lord Halifax to Newton's poverty. Here he was, the world's greatest living scientist, and his income was barely enough to exist on. Halifax felt that England owed something to her great man. With a little time and effort he got Newton appointed as master of the mint, salary equal to $7,000 a year. What a fortune that must have seemed to Newton! It is not surprising that he gave his time devotedly to his work and neglected the poor-paying business of science.

16

Indeed, after the publication of his work on differential calculus, science got nothing more from him. He continued to write, but now theology held his interest. All his life he was deeply religious, and not once does any doubt seem to have entered his mind—either as to form or substance. Hence, to present-day readers, his religious papers are of little interest and not infrequently they are credited to his dotage. Certainly if anyone wants to take the time to look at them, one will find that they are not the work of a glittering and unusual mind.

Set it down then that Newton's work, for some reason or other, ended at forty-five, and but for an accident would have ended at twenty-four.

As master of the mint, with the income that position brought, Newton could have lived like a prince. Instead he lived simply and alone, spending much time closeted with his books and laboriously writing out papers, of no value, on theology.

In 1703 one more honor came to him. He was elected

president of the Royal Society and was reelected annually for twenty-five years.

17

For forty years after Nature wrote "The End" to his genius, Newton lived on. Honored and respected by all, he was apparently loved only by the members of a very small group. He lived with a niece—a lonely old man, slipping into the twilight.

Disease caught him late in life, and his last years were seldom free of pain. Something went wrong with his kidneys and there was talk of a stone. In addition there was gout. But no complaint came from him. He bore his sufferings patiently, wisely looking ahead for the final relief.

What a long way he had come since those old midwives waddled hurriedly forth in quest of help for a dying baby, weight three pounds. That baby had been born into a universe whirling in chaos. Eighty-five years have come and gone, and this old man has banished chaos and established order.

18

On February 28, 1727, Newton, feeling well and strong, went into London to preside at a meeting of the Royal Society. Many of the members who had known their president for a quarter of a century never again would see that figure, crowned with its snow-white hair.

March fourth, he was back at home at Kensington, sick unto death.

Two doctors attended him. Again, stone, said they —standing at his bedside helpless. For ten days he was twisted with pain, but on the fifteenth there was some relief, and hope brightened. Was it in this brief

interval of waiting for the final blow that he pronounced those marvelous words, fit to sound in the head of every man who calls himself a thinker?

"I do not know what I may appear to the world, but to myself I seem to have been only like a boy playing on the seashore, and diverting myself now and then finding a smoother pebble or a prettier shell than ordinary, while the great ocean of truth lay all undiscovered before me."

And again he said, turning wearily on his bed:

"If I have seen farther than Descartes, it is by standing on the shoulders of giants."

No arrogance here; no moaning with Tycho, "Oh, that it may appear that I have not lived in vain!" Quiet modesty, a quiet slipping away, through the dark veil, into that pure light which he deserved so thoroughly to enjoy. . . .

*Chapter Nineteen*

# FROM LEEUWENHOEK TO LAPLACE

DEAD were the Dark Ages. Dead, or gasping its last, was scholasticism, as the seventeenth century aged. Here and there all over Europe, flaming banners bearing a great question-mark, were flung to the rising sun.

For three centuries Science had gone soft-footed and spoken in frightened whispers. The voices of those who had dared to speak aloud had been lost in the roar of a funeral pyre. Three centuries of a whispering campaign, and Science found itself a lusty youth, with a voice changing to a deep rumble. Never again was this young giant's voice to die out of the world; but rather to gather volume, to become a clamor, a shouting and a tumult in all men's ears.

Strange to note how wisdom thrived as tyranny staggered to a fall. The lords and masters of Europe could not crush this spirit, driving toward mental and political freedom. They were more than likely to be crushed by it as it swept into revolt. Louis XIV, shrieking, "The state? I am the state," cannot stop this monstrous intellectual.

It cannot be stopped in Italy. The war lords of Germany cannot stop it. The Czar of all the Russias cannot stop it. Spain alone is successful in binding it; but this victory will make Spain, when the twentieth century dawns, an anomaly among nations, still shadowed with medieval superstitions.

2

No longer were there isolated workers. The line of advance was thin, but here and there searchers touched elbows. There was the Lynx Eye in Italy, there was the Royal Society in England, the Academy in France, and others soon were to spring into enduring life. Anthony Leeuwenhoek, born 1632, peering for the first time in the history of the world at strange microscopic bugs in a drop of water taken from the canal of his native Delft, could get aid and encouragement from the Royal Society in London—and win immortality as his reports are saved for the future.

Huygens, another Dutchman, born in 1629, turned his telescope on Saturn and solved Galileo's moons by proving them to be not moons but a ring. That there was a moon, a real one, and this the largest of Saturn's satellites, he also found. Again he turned his hand to mechanics, picking up a thought thrown out by Galileo, and brought to man the pendulum clock. But Huygens was not lost in Holland. France beckoned him at the founding of her academy, and Paris knew him for fifteen years. A daring man, Huygens, for he defied Newton, and stood firm for his wave theory in light. Newton could scoff at it but time was to accept it, and volumes were to be written about this "ether" that Huygens's imagination tossed into space.

3

Nor was Germany without her great figure, a master of men, rivaling the mighty Newton, and growing vaster. Leibnitz, the Aristotle of the seventeenth century, was born at Leipzig in 1646. He it was who organized the Academy of Science at Berlin and helped form similar bodies at Vienna, St. Petersburg, and Dresden.

Born a strict modern, he lifted almost the first voice in criticism of the practice of teaching Latin, by which, he said, "the keenness of the intellect is often dulled." He branded as childish the custom of calling a man ignorant simply because he did not know a dead language.

Leibnitz clashed with Newton over his differential calculus. Each claimed it; each, apparently, worked it out for himself. Credit, and much of it, goes to Leibnitz for giving to this branch of mathematics a clear, simple notation. But Newton and Leibnitz each owed a big debt to Pierre de Fermat, born in 1601, whose work on curves gave the world its first hint of this differential calculus. A plain, modest genius, this Fermat, to whom modern mathematics should pay reverence.

Edmund Halley, as we saw, was friend and disciple of Newton, and gave Newton's "Principia" to the world.

Fourteen years Newton's junior he outlived his master by fifteen years, dying in 1742, one hundred years after the birth of the incomparable one. He did not always lean on the work of others and stand only in reflected glory. He had his own thoughts driving him to discovery and theory. Two, at least, of his ideas were popular and have become common knowledge: he credited the aurora borealis to magnetic origin, displacing, not killing, the theory of sunlight reflected from ice fields; and he gave for the first time a sane explanation of comets.

To Halley these rare visitors were not dark messengers of death and misfortune helter-skeltering through space. To him, having Newton's work in mind, there was no disorder among the stars. Comets then must be natural and regular. He traced the rec-

ords to see what he could find. Sure enough, this fiery fellow had appeared through the centuries at intervals of about seventy-five years. Then there must be an orbit, and computation should reveal it. He set himself thus a gigantic task, out of which grew his predictions, verified by the return of the comet in 1759 and at approximately regular intervals ever since, last appearing in 1910. Watch for it again around 1985. Also don't forget that in 2255 another of Halley's comets is due to arrive.

4

Over in Scotland Joseph Black, born 1728, was delving at chemistry. He took some hard hits at the idea, then prevalent, that there was a principle in fire, phlogiston, that entered into things burned. His experiments contradicted this notion and led him to the discovery of what he called "fixed air." He weighed his material before and after, thus for the first time bringing the balance into use in chemical experiments. He studied and wrote of latent and specific heat—and his work pointed the way for James Watt and his steam-engine.

But Black was sickly, occupied with professional duties at Glasgow, and so carried nothing to conclusion. He published little and was not interested in establishing for himself a place with posterity.

5

So Henry Cavendish, a timid recluse and wealthy, could carry forward this work on the air. This tall, thin, silent Cavendish, born in 1731, grew to middle age dependent on his father's bounty. But inheritance made him at forty one of the richest men in England. This fortune did not at all change the course of his

life. Once a year his tailor came to provide him with a new suit of clothes—the old ones by that time, after a year's constant wear, frayed and shabby. A woman-hater, this man sentenced himself never to marry. More than that: he instructed the woman servants in his house to keep out of his sight, on pain of instant dismissal. He wouldn't see them or talk to them. But every day he left a note where the housekeeper could find it, telling her what he wanted for dinner.

Method and system could scarcely go further than the point to which Cavendish carried them. In getting a book for his own use off the shelves in his own library, he never failed to charge himself with it and to mark the book returned when the volume went back to the shelf. One shudders to think what would have happened if, growing careless, he had jumbled his records.

He went nowhere except once a week to dinner with the members of the Royal Society.

There he stands, then, a gaunt, frightened man, methodically prying at Nature's secrets. Never excited, never in a hurry, never bungling, he sought for and found strange truths, beautiful truths, his mistress Science, to whom he devoted his life, treating him kindly, smiling at him through half-closed eyes. So the queer man, unloved and unloving, moved through eighty years of life.

6

Cavendish found and weighed Black's "fixed air." He went farther and discovered hydrogen, which he called "inflammable air." With these things, not yet called gases, he made many experiments. He found that common air, containing nine parts of fixed air—carbon dioxide—would not support fire.

Next he turned his attention to electricity and made many careful experiments, most of which he kept to himself. Not for fifty years after his death were his notes published. By then the world had moved well in advance of anything Cavendish had done.

Ever since the dawn of time, water, like air, had simply been taken for granted by scientists. It was a simple element and there was no use bothering one's head about it. But this Cavendish, who bothered his head about everything, would take nothing for granted. It seemed to him water deserved a little thought.

Imagine then the grim, timid satisfaction of this man when he disclosed the compound nature of water. When he sent his electric current through a mixture of common air and hydrogen, Cavendish was not prepared for the startling result. Whence this moisture that he found, along with the loss of volume in his air? He tried again, this time increasing the proportion of hydrogen. Sure enough, with the passing of the electricity, the volume decreased and there was an appreciable amount of dew, of water, pure water. A pretty experiment and complete, once oxygen is isolated and duly named.

## 7

A great push forward was given to chemistry by Black and Cavendish, helped by Priestley, a contemporary born in 1733. With this Joseph Priestley, America, for the first time, gets into the world-picture of science. It seems fitting, too, that this first lead from the Western World should have been made by a rebel. Priestley was born a non-conformist, and the established church could not induce him to change his mind. Later he became a Unitarian.

Not only in religion did Joseph sound his rebel note. As early as 1765 he was telling the English government that it was making a fool of itself in its treatment of the American colonies. Not that anyone paid any attention to him—at least not at that time.

Being a minister and working at it most of the time, didn't keep Priestley from delving into science. That's the kind of mind he had—always wanting to know things. This trait led him, while still a child, to study Latin and Greek, and when too ill to go to school he tackled Syriac, Chaldee, Arabic, and Hebrew, and a little later, French, German, and Italian. In addition, he read everything he could get hold of that dealt with philosophy.

Apparently he was twenty-eight years old before he started the study of chemistry. Once at it, he made fair headway, but method and system were never his forte. He himself said his discoveries were the result mostly of luck—and it seems likely he knew.

Lucky or not, he did one thing that keeps his memory green. He discovered oxygen—what he called dephlogisticated air. This phlogiston theory, interesting now only as an antique, was the result of work done in the last part of the seventeenth century by two Germans, Becher and Stahl. Stahl said there was something dispelled by heat, and this something he called phlogiston, "the combustible substance, a principle of fire, but not fire itself." Stahl hadn't the least idea that in burning, an element in the common air is consumed.

That's the idea Priestley clung to all his life. It didn't stop him from fooling around with the reddish brown powder obtained by calcining mercury. Just to see what would happen, he heated this powder, red oxid of mercury, with a burning-glass. He found a gas was

given off in which a candle burned better than in common air. Moreover, he was amazed to find that mice would live in this air and grow frisky and active and on the whole seem to like it.

Dephlogisticated air, he called it. But the fact is, that for the first time in the history of the world, oxygen, soon to be so named by a Frenchman, had been separated from the common air and held captive in a glass jar.

Cavendish had upset the idea of water being an element. Now Priestley tore up another element—air. Is there nothing sacred to these scientific chaps?

8

Priestley did other things, not so important. Among them a large number of books on religion and what he called philosophy, happily not read by anyone today. In them doubtless he dreamed of life everlasting. But in that bit of reddish brown powder lay the spark of immortality for Priestley.

Not born for a placid life, he was driven by his impulses and emotions this way and that. They would not let him remain quietly a country preacher, would not let him close his ears to those shouts of defiance from across the Atlantic, to those later hoarse cries from Paris.

At Birmingham he seemed settled, comfortable, secure, and there he studied, experimented and argued about man and religion with Dr. Erasmus Darwin, the grandfather of Charles. Rare times those two great talkers must have had—hating each other's ideas, loving the man back of the opinion.

This quiet could not last; it was disturbed rudely. In July, 1791, Birmingham's Constitutional Society planned a dinner to celebrate the fall of the Bastile in

Paris, two years earlier. The respectable citizens of Birmingham could not endure that. They organized a mob, whisked out that celebrating dinner, said, "This is as good a time as any to get rid of this chattering minister, not of our faith and therefore certain to be damned."

Priestley and his family heard the roar of this righteous mob and ran for their lives, escaping empty-handed. Its prey gone, the mob sacked the house, burned the chapel—sending up in smoke and soot, a foul cloud against Birmingham's night sky—the work of a lifetime.

Priestley sought refuge in London, sure of safety there. Safety? Yes, but hedged by "troublesome attention." His three sons, already in America, urged him to come there. Joseph and his wife sailed April 7, 1794, bound for New York. Two months, lacking three days, they were at sea, landed June 4, and went on to Northumberland, Pennsylvania. There they settled down, hoping for better times.

For ten years Priestley elbowed the wilderness on the west while his eyes were turned east. He was never again to see the shores of England. On February 6, 1804, he dictated changes to be made here and there in his books; cleaned up thus, the day's work, settled back and fell quietly to sleep, with no more waking for him, ever, in this world.

9

This movement, breaking furiously on the shores of the eighteenth century, slights no branch of science, not even this bewildering, terrible thing—electricity. It was practically unknown when the seventeenth century died. It crackled vaguely through the pages and work of William Gilbert, whose book, "The Magnet,"

held the world's knowledge on this subject. Francis Hawksbee as he forced air through mercury, held in a vacuum, noted the light that sprang into being. Could it be that what he saw was electrical? So he shrewdly guessed.

Gray and Wheeler took up the work and found that conductivity differs in different substances—a discovery that helped Dufay, who startled himself by finding that there are two kinds of electricity, positive and negative. Watson carried on, asking the rate at which this "fluid travels." Tested it, then, on a wire 12,276 feet long. Time? None. The distance was traveled instantly!

And Ben Franklin, greatest mind ever born in the Western World, had also an idea worth trying out, likely to prove dangerous and certainly thrilling. The electric spark, with its crackle was known. Franklin pondered that, looking at a Philadelphia thunder storm. Spark and crackle, flash and roar. Were they identical? It seemed plausible—if only one could pull some of that lightning down, test it, know what it really was.

How to bring that zigzag flash to earth was his problem, solved when he thought of a kite, flying cloud-high while thunders roar. He flew one. The rain wet the string, the cord swelled, a spark leapt from the attached key to Ben's knuckle. This thing, then, that tumulted above was only electricity leaping from cloud to cloud with natural accompaniment of flash and crash. Such an experiment proves nature simple—if only one knew what this electricity we play with were!

The clouds were thus robbed, partly, of their terror, and the name of Benjamin Franklin went round the world. Zeus was despoiled of his thunderbolt—and

men's minds grew ripe to receive startling truths, even about their own bodies.

10

All this had opened man's eye, held tightly shut for centuries. The crash of falling idols had startled him awake. James Watt, canny Scotsman, could moon over his steam-engine—and no one accuse him of being in league with the devil. Not even when it worked, and the roar and puff of it were heard for many miles. Another giant unbound, ready to crisscross the world with rails of steel, to scream his warning, to take his toll of human life, to play his bewildering rôle.

Watt, dour and set in his ways, never dreamed he was the apostle of a new era. Fate marked him so. The age of invention had dawned.

The spinning "jenny" and the power loom crept out of the minds of men, while a shrewd Connecticut Yankee, Eli Whitney, crowned King Cotton with the "gin" that made large-scale production possible, gave slavery a new lease of life, and made the Civil War inevitable.

In England another stranger sight, man never saw before: gas that burned and did not explode. This miracle was made by William Murdoch. Here was a light for home and street, stronger than many candles. What a wizard, this Murdoch! Never can man hope or imagine a better light than this!

11

Shocking days, those fierce ones of the eighteenth century. One found it impossible to tell where one stood from minute to minute. At the head of creation, image of God—there one had stood a moment ago, where one's fathers, backward into dim time, had stood.

But Carl von Linné, Linnæus, a Swede, mulled over his classifications, fussing and fuming—a born classifier. Plants and animals he dragged into his system and, yes, by heavens, man himself. Him, this Swede classified as head of the apes! *Homo sapiens* in the order of Primates, together with the apes, lemurs, and bats!

In this Linné, science of the future had found its man. System had been needed. Studying and comparing without system the worker goes in a circle. Linné set all that right—helping the wiser ones who came after him. It was this Swede who first threw Aristotle's plan overboard, and built for himself and the world a much better one.

It is significant that men were thus slowly prepared to see the throne of special creation dragged from under them. It is not surprising that they clung to that royal seat; surprising, slightly, that some yet cling to it. Not everyone could see, instantly, that the old glory was badly shop-worn and that a new and more radiant apparel and a higher and more beautiful throne awaited at the hands of this despoiling science, now busily rending the old vestments one had thought were woven of imperishable purple.

12

How men cling to old fancies, light as air and of the substance of moonshine! A God of caprice and petty rages was such a fancy clutched fiercely to the common breast.

Hold it who might, there was one, born in Normandy, March 28, 1749, who would not hold it. He was to be called atheist and heretic, but would never kneel to a fickle and changing God. Pierre Simon Laplace, son of a small farmer, was to set his name ringing around the world, and die a marquis, after bar-

tering much that wise men think valuable, to win for himself a ribbon and a title.

There is no uncertainty in stars and planets, shouted Laplace over and over during his seventy-eight years of life. Set to and proved it with hard figures, hard for the unmathematical mind to follow. Proved it was, and his universe stood sure and firm.

But whence this universe, far-reaching, an endless journey across though one traveled with the speed of light? Laplace asked that question, eying the stars, digging into the works of others. Immanuel Kant, in 1755, offered an idea worth considering. Laplace went further, and appropriated it as his own, put it into his system of the universe—and made no mention of this small seed sown by the great German philosopher

Branding it, "nebular theory," and tacking his own name to it, Laplace gave the idea to the world. Frightful to all good church people it was, because here was a system of creation that made no mention of God, in which there was no room for a personally directing God. This world, those neighboring planets, thrown off by the parent sun, shrinking from a state of expanded, superheated gas to the small solid upon which you set feet or at which you train your telescope, had need only of a God infinitely remote before the birth of the nebula out of which sun and planets evolved.

This, in a word, is the famous nebular hypothesis, "most sublime idea ever tossed off by the mind of man." Little wonder it captured the imagination of thinkers and held sway for more than a hundred years, until two Americans, Chamberlin and Moulton, voiced a new theory in a more acceptable form.

Little wonder, too, that good churchmen denounced it. It robbed them of an intimate deity who punished and rewarded. But the work of destruction had only

just started. Worse things were in store for those who could not unleash their imagination. Happily for man and the mind of man, the great and wise of all churches were able to find their God at a distance and to cling to Him with unwavering faith. Neither Laplace nor another could shake those who, having eyes saw, and having ears heard their God across an enormously expanded universe, which suddenly was grown unbelievably ancient. . . .

*Chapter Twenty*

# LAVOISIER

BLACK, Cavendish and Priestley, as we saw, struggled with nature and brought forth startling truths. But a greater than they was needed to analyze these facts, to explain them, to make them stand on their own feet in the face of ignorance and doubt. And the greater one was at hand.

Louis XV was on the throne of France when Antoine Laurent Lavoisier was born in Paris August 26, 1743. It was a Paris still devoted to its king, but a Paris likely to hurl the next Louis and this baby Antoine into a cataclysm. This monarch, called the Well-Beloved, was to totter into his grave—beloved of no one. His successor, the amiable locksmith, was to prove totally unable to cope with terrific cross-currents, was to be caught up, flung hither and yon, and to come to a miserable end. Time only was needed.

Antoine nor the dauphin Louis knew anything of this black future. Each looked forward hopefully; one to the throne; the other to a different sort of glory and immortality. This dauphin was to be lucky enough to die and leave the whirlwind to his son, eleven years Antoine's junior. Long gathering, this tempest was to sweep with hurricane fury through the streets of Paris. Fifteen years passed after the Well-Beloved quit the throne, before chaos roared around the feet of Louis and Antoinette.

## 2

Antoine Lavoisier was thirty-one when Louis XV died. Thirty-one and already famous. Opportunity, the best that France had to offer, had been given him. His lawyer father sent him to the Mazarin College and did not frown upon his taste for natural science but encouraged it. He gave the boy a chance to study mathematics, astronomy, and chemistry with tutors outside the college.

Whatever in the shape of knowledge that came his way was grist to the mental mill of Lavoisier. He dabbled in everything, and everything he illuminated. He was twenty-three when he received his first gold medal, for a paper on the best way of lighting a large city.

As you see, there was a clear, organizing head on this chemist's shoulders. It brought him early honors; it was to bring him later tragedy.

He set no bounds to his activities and began giving advice to a government rushing toward distraction. Experimental agriculture—he gave advice on that. Paper for currency that could not be counterfeited—he answered that in detail. He threw out hints on gunpowder and dashed off papers on mesmerism, water supply, invalid chairs, and divining-rods. All was grist.

Water by repeated distillations is converted into earth. That was a common belief of scientists and laymen. Not so, said Lavoisier, and he made experiments to prove the silliness of the idea. He was, from the first, a disturber, a rebel, in science, who didn't care a rap for gray-bearded traditions not founded on fact.

3

Chemistry for fifty years had been stirring mightily, but it was still in chains. The liberator had not appeared. Lavoisier assumed that rôle.

Progress was blocked by the phlogiston theory. No right idea of combustion, of air, was possible while that lie stood. Antoine tackled it, not sure where he would come out. "Let's at any rate settle it," he said. "Let's find out what it is we're all talking about. If there is such a thing as phlogiston, we'll run it to earth, drag it out and have a look at it. If it's there, my balance will discover it."

In a sealed note which he gave to the Academy of Science November 1, 1772, he made a report not in support of phlogiston, but the opposite of that. "Sulphur and phosphorus when burned increase in weight because they have absorbed air. But litharge burned over a charcoal in a closed vessel, weighs less." These were the two facts that his balance gave him.

The phlogiston theory persisted, however, until Priestley told him of "de-phlogisticated air," which led to further experiments and the birth of the word oxygen (acid-producer) coined by Lavoisier—which rang the knell of phlogiston and gave the world a real idea of combustion.

But hydrogen remained a mystery. It had to be cleared up, and the Frenchman undertook to do it. Why should hydrogen be evolved when metals are dissolved in acids? Why should hydrogen be absorbed when calces are reduced to a metallic state? Two good questions which Lavoisier, with the uncredited help of Cavendish, answered.

He had first to know something about hydrogen, and the hint came to him from the eccentric English-

man—though Lavoisier never thought it worth while to admit this. Oxygen and hydrogen combined form water. Steam passed over red-hot iron wire loses its oxygen and lets the hydrogen pass on. So much he owed to Cavendish; the lucid explanation was his own:

The solution of metals in acid depends on the decomposition of water, the oxygen uniting with the metal to form a calx while the hydrogen escapes. When calces are reduced to the metallic state, the hydrogen seizes on the oxygen to form water, and the metal is left. Simple, isn't it? But it took the genius of a Lavoisier to vision exactly what occurred and to put it into words that all could understand. With the appearance of this statement phlogiston passed forever from the face of the earth—where there was no longer any room for it.

4

For many hundreds of thousands of years men had lived on this strange world before Lavoisier appeared. Through all of those ages men were breathing—and without the least idea what went on in their own lungs or what it was they breathed. Air, they called it, and let it go at that.

Lavoisier wasn't satisfied with so slipshod a statement. He wanted to know. He had a theory, but he also had a laboratory, and he put his theory to the test. It worked. The only part of air that would support animal life was oxygen. Breathing, he said, is a form of combustion. Oxygen disappears, nitrogen remains unchanged, but to it has been added carbonic acid. The same thing happens when a candle is burned in an air-tight vessel. The world had waited untold ages to learn the secret of a vital process, and there it was as plain as day.

But there was another and greater problem that bothered Lavoisier—one that had troubled the dreams of men from the moment man became a thinking animal: Why doesn't the world wear out? With all these plants and animals living upon it, what prevents its quick exhaustion? There the imagination of this Frenchman had free scope, and he hit upon a brilliant answer:

Plants feed upon the air and water, and animals upon plants or plant-eating animals, and each in turn eventually gives back to the good old earth everything that has been absorbed. Fermentation, putrefaction, and combustion restore to the earth all that was taken out. Life moves in a circle—dust to dust.

5

Had Lavoisier remained only a scientist, he might have lived. Lamarck could do so. But the wild spirit of this handsome man must dabble in many things. He had an itching palm for politics and statecraft, and doubtless found in his own head an answer to France's unanswerable problems. He had much to live for—but he could not escape fatal activities.

There was Marie Anna, for instance. Beautiful and accomplished daughter of the tax-collector Paulze, she laid her spell upon Antoine. Nor was she indifferent to this distinguished-looking man, not yet thirty and famous, who seemed destined for high places. That was a courting—in the midst of the world's maddest city! The matchless Marie Antoinette had only recently risen like a morning star out of Austria, bringing to her boy husband and to France the glory of a flaming personality. The court, and those who aped it, were caught in a whirl of breath-taking escapades.

In the midst of this fever of intrigue and passion

Antoine and Marie Anna met and loved. In 1771 they were married.

Father-in-law Paulze looked on, well pleased. And laid brave plans. He stood well in favor at the court, being able to turn a phrase as tidily as any. Nor was there any reason to be ashamed of this new son who was an adjunct to Tax-Collector Baudon.

Not four years passed before Lavoisier was taking care of the problem of a nation's gunpowder. It was he who put a stop to that vexatious search of Paris cellars for saltpeter, and at the same time increased the output of this so badly needed explosive. Badly needed, indeed, for France from now on until the final disappearance of the mad Napoleon, will be one red glare, from border to border, of detonating gunpowder.

6

Could such a man escape the Revolution? He could not stand aside, as Lamarck did, and quietly watch the whirlwind sweep by. Not Lavoisier. He was in the thick of it. In 1789 he made a report to the National Assembly, with the roar of a falling Bastille still in his ears. Two years later this scientist who must be dabbling in everything was commissary of the treasury, with a system of accounts unexampled for punctuality.

But his accounts, punctual or otherwise, could not save him. Was he trying to carry water on both shoulders? On one side was the court, from which he had received many kindnesses; on the other, the sansculottes, to whom he owed nothing, but the wild justice of whose prayers must have touched him. How shall a man act in such a crisis? But if one does wholeheartedly and with rare punctuality the business entrusted to him by a revolution, can more be asked?

Yes, questions can be asked. They came thick upon a punctual commissary after 1791. Down with the tax-collectors, said the Assembly. Down with them, roared the people, seeing in the legislative act a criticism of officials who could never be popular in any country.

Lavoisier stood head and shoulders above his fellows—his name had filled the world as Father of Chemistry. Around him, then, the pack snarled. Marat, not yet extinguished by Charlotte Corday, the beautiful one for whom it would be sweet to die, penned his crabbed attack and hinted that Lavoisier lined his pockets while looking out for the nation's gunpowder. He went further and threw slimy suspicion over the whole Academy of Science.

Was not this Academy, Marat asked, chartered by a king, and was it not now full of rank royalists who secretly hated poor people and who out of their cunning might concoct some frightful means of beating back the glorious revolution? On this and similar notes Marat harped in his "Friend of the People." Nor were there lacking brighter ones than this blear-eyed horse doctor, to take up the cry. Among them note Fourcroy.

Antoine François, Comte de Fourcroy, was himself a chemist and a popular lecturer at the college of the Jardin du Roi. Only a little while ago he was proud to be known as friend and disciple of Lavoisier. All of that, of course, was before the roar of the mob drowned out the fine phrases of the aristocrats. With the coming of the revolution and the rights of man and the swift rise and fall of the guillotine, one could change one's ideas and one's friends—and strive frantically to keep one's head where it belonged. In a moment of blind terror and passion ordinary standards of decency are likely to be forgotten.

It was Fourcroy who rose at a meeting of the Acad-

emy and suggested a purging. "If there be members who are lukewarm in this great fight for liberty, kick them out. We patriots should not be contaminated by their presence," he said in effect, while casting a suspicious eye over his brother scientists. Some of them might quail but in general these wise ones sat tight. They refused Fourcroy his purging.

But this man, fighting to save his own head, will not be beaten; he will return to the attack.

## 7

Lavoisier, handsome and indifferent, went about his business. Marie Anna was stedfast, refusing to be alarmed by this beast that surged through the streets of Paris. That beast was not of her world; but its claws had reached to high places, and who in a world turned topsy-turvy could feel safe?

Lavoisier went his way, but there was no real peace for him after that abortive attempt at purging by Fourcroy. In August, 1792, he was forced out of the arsenal and away from his laboratory. He set up another laboratory and went about his researches.

In November of the same year, an assembly, striking a tentative blow at the Academy, commanded: "Take in no new members, let your vacancies stand—until further orders from us." Was the Academy to be ended?

Next year, in August, the light shone again, and Lavoisier stuck his nose out of his laboratory. The Constitutional Convention passed a decree for uniformity of weights and measures, and called upon the Academy for help in putting the act into operation. "Ah, then, it seems these wild law-makers cannot get along without us," said the scientists, smiling and hopeful.

The time for smiling had not yet come. Fourcroy, whom they had treated with cold indifference the year

before, was not beaten and done with. A man intent upon saving his own head is never done with. This decree, which brought Lavoisier out-of-doors, was not yet a week old, when Fourcroy rose in the Convention to denounce the Academy. "Denounce" is too strong a word, say Fourcroy's friends. At any rate, he persuaded the Convention to suppress the Academy. That, one sees now, was the beginning of the end.

A little later all of these ex-tax-collectors, or as many as a busy Convention could lay its hands on, were arrested, charged with misappropriation of public money.

Once more Fourcroy acted—or, to give him the benefit of the doubt—did not prevent action. A committee of which he was a member struck Lavoisier's name off the commission of weights and measures.

8

All of this happened in the late summer of 1793. When torn from the arms of his wife and carted away to prison, Lavoisier was at work on the study of perspiration—at that time a mystery, baffling to chemist and physician. His experiments could wait, but the strong arm of the revolution could not. His father-in-law Paulze, his life-course almost run, was also arrested and landed in jail. Marie Anna was left alone with her thoughts.

For months Lavoisier was in prison, scheming as all there schemed; laying plans that came to nothing; smuggling out notes to Marie Anna; hoping, despairing. And all the time the guillotine was busy.

Old Paulze grumbled but would not take seriously the fix in which he found himself.

Outside, in Paris, frenzy ruled. One could not trust one's own brother—the head on one's shoulders wag-

gled so uneasily. Beneath this froth of insanity, reason and kindness were struggling to get to the surface. But Robespierre was still master, and his soul had sickened into a strange cruelty. No plea for mercy could reach him.

The Red Terror, of which you read much, lasted all through the winter of 1794. But as spring came into Paris, those in prison saw and heard, or sensed a change, and turned hopeful. Tallien was at work; others were at work. There were signs, upon which one could not as yet put a finger, that Robespierre was gasping toward a finish. Yet Sampson was still busy, and the guillotine was still busy, and for many of those who hoped there was no hope.

9

Meanwhile Lavoisier, this man, described as "tall and handsome, with a winning personality," lay in a foul prison. For fifty years he had marched forward triumphantly as one of the world's great ones. He had been courted, flattered, and honored. A queen had won him with her smile. A stolid locksmith king had nodded his approval. All of the wit and the beauty and the charm that was Old France had circled around him.

He had known no hardship; no poverty, no failure, no disgrace. For fifty years the little gods had been kind to him, and then, suddenly, they deserted him.

On May 2, 1794, it was moved in the Convention that Lavoisier and other ex-tax-collectors be at once brought to trial before the Revolutionary Tribunal.

No justice was to be had at their hands. Lavoisier knew it, his associates knew it, Marie Anna knew it. Even old Paulze was at last aware that something tragic was shouldering him.

They were brought to trial. Short shrift there. The Tribunal was easily convinced of their guilt, being already satisfied on that score. "Guilty, guilty." That was the word for the whole twenty-eight of them. "To the Place de la Revolution with them, and let there be no delay."

"But, sir"—it was Lavoisier speaking—"I am busy with an experiment on perspiration in my laboratory. I ask only time enough to complete that work that I may confer one more honor upon my beloved country, France."

"Enough," cried Coffinhal, striking the table in front of him. "Enough. The Republic has no use for scientists."

The proud genius made no further plea. He looked at his old father-in-law. He thought of Marie Anna. He remembered his life work. He had nothing more to say to Coffinhal or the Tribunal.

On the morning of May 8, 1794, these twenty-eight condemned men were loaded into tumbrils, and their last fearful ride began. These men knew how to die. At the Place de la Revolution the tumbrils halted, and the prisoners dumbly awaited their turns. Probably Lavoisier's last words were whispered into the ear of trembling old Paulze, who leaned on the arm of his son-in-law and could scarcely breathe.

The knife rose and fell twice. Two heads had fallen. It was Paulze's turn. "Courage. It is but an instant and then—eternity." This or something like it, Lavoisier whispered to Paulze and then the two were parted.

Lavoisier was next, fourth in the long line of twenty-eight.

So had the Father of Chemistry been whisked out. "It took but a moment," wrote Lagrange, "to cut off

this head, but another like it cannot be produced in a hundred years."

"Chemistry is a French science," wrote Wurtz. "It was founded by Lavoisier, of immortal memory."

This was the genius and the worth of the man whom a Republic in revolution could spare!

*Chapter Twenty-one*

# LAMARCK

STAR-GAZERS, chemists, electricians—all were busy in this eighteenth century, striving with might and main after the subtle, the illusive. Mystery shed its mask at their approach. Fable and legend went glimmering, together with their spawn, superstition. There was a clearing of men's minds—as of a sudden high wind sweeping through an age-old garret, tearing off shutters, scattering dust and débris, letting in, after centuries, pure air and sunlight.

But in this cleansing, some shadows hang in dark corners, glooming the mind of man. This of special creation, for instance—how it clings! "The last thing to die in a man is vanity." God removed Himself from the exacting duties of running universe on universe, and took time to model man with His own infinite hands. What a solace to the two-legged animal afraid of his own weakness!

Believe this, and one's supremacy as the lord of created things is sure and lasting as the eternal hills. But if one were at last ousted from that citadel?

2

For ages this belief had closed the door on man's study of the physical part of himself. For every hundred books written, since the birth of Christianity, on the spiritual side of man, there had been less than one-tenth of one devoted to man's physiology.

Nor were the beasts of the field and the small things that crawl or fly thought to be worthy of study. These neighbors of man have no soul, and only the soul, unseen, unheard and untouched, deserved serious consideration. Since Aristotle wrote his natural history, little had been added to man's knowledge of himself or of his companions. Here and there a doctor—a Galen or a Harvey—might probe after truth, but he had not touched the common people. Regardless of them, the common people had gone their sturdy way, rejoicing in their intimate kinship with God and hugging disease to them as a divine visitation.

But not forever could the eyes of science remain closed to life and the small mysterious happenings in plant and animal kingdom. Wits were being sharpened in the hard school of "Why?" Linné, with eager delving, studied whatever came his way, bent his vast industry to classifying, making easier the road for those who came after him.

Buffon arrived, shouting along the path Linné had blazed. A voice this man, an arresting, colossal voice. No classifier, he; no midnight student with eye glued to microscope, struggling through the years to learn one new thing and give it modestly to the world. Not he. Buffon grabbed, with both hands, whatever he wanted, slapped it down instantly on paper, sent it whirling through the world to serve his purpose, in a loud boisterous way. He startled with that bull voice all men out of nodding indifference, stirred them to look about, to notice the myriad life that fought constantly for a small place in the sun.

A loud voice, this Buffon, ringing out at just the moment when in all Europe, the century-old sleep of man was growing troubled, fitful, with uneasy turnings and the half-wakeful query, "Is it not yet dawn?"

3

France, flowering under Louis XIV, was rushing into swift seed. The "Well-Beloved" still sat his throne, dallying with his mistresses, when a world-shaker was born out there in Picardy on the first of August, 1744.

Jean Baptiste Pierre Antoine de Monet, world-famous as Lamarck, was the youngest in a family of eleven. Not rich, that family, but touched with nobility, and given strongly to military exploits. Jean, with his brothers storming through the camps of Europe, was selected for the quieter, safer life of a priest. One brother, the eldest, had already been killed at Bergen-op-Zoom and others were marked for early, violent deaths. This puny youngster, Jean, surely could be saved for a saner life.

That was not Jean's idea. The trappings and romance of wholesale murder thralled him, but parental authority overruled, and he went quietly to the college of Jesuits at Amiens, busied himself, half-heartedly, with his books, dreaming of hard-earned glory for God and king. Release came with the death of his father.

4

France was waging her usual war with Germany, and over at Bergen-op-Zoom troops were concentrating, preparing for a final rush. With all restraining authority vanished into the grave, Jean instantly quitted the College of Jesuits forever.

Sixteen years old, burning with war fever, he was stopped by the question of how to join the army. But women are always anxious to rush men off to war. Madame de Lameth was familiar with certain officers, and a letter from her would serve as passport and credential.

The letter was applied for, written. There remained now the question of how to reach this Colonel de Lastic, of the regiment of Beaujolais.

Fever in the blood is not to be stopped. Lamarck managed, somehow, to get a raw-boned, antiquated horse, to get as squire a village boy, no better or not so well mounted as himself. And these two youngsters set out on their journey, fiercely determined to destroy themselves. What became of Lamarck's simple companion? Did he die on the first day of hard fighting? Or, without a letter from Madame de Lameth, did he fail to get into the army? Did he live long and tell his children in after years, "I rode once with your great Lamarck"? History has no answers to these questions.

History, however, records the brief military exploits of Lamarck. The letter was duly presented. Soldier de Lastic read it, eyed the bearer, found him a puny youth—little material out of which to build a fighter. The colonel, full of plans for a bloody morrow, dismissed the new recruit, thought no more about him. But Lamarck thought, and acted promptly by attaching himself to a company of grenadiers. Strange that he should have selected this one company of all others, for on the next day it bore the brunt of the battle of Fissingshausen. In its exposed position, Lamarck's company was raked by the German fire; officers and men fell; the rest of de Lastic's troops gave way; these grenadiers did not give way.

Only fourteen men remained, and the enemy's fire did not slacken. Lamarck made himself captain—all other officers lying dead or wounded. Bearded grenadiers approached the boy, suggested he should order a retreat. But Lamarck was firm. He would not re-

treat until his superior officer ordered him to do so. Fortunately this superior officer missed his grenadiers and sent an orderly to bring them in.

For this evidence of bravery, Lamarck was at once made a lieutenant. Yet in spite of this bright beginning, his military career was brief. Following the defeat at Fissingshausen, the whole French army retreated. Lamarck was at Toulon and later at Monaco. His life as a soldier ended at the latter place. While he was there, a playful companion raised him out of his chair by his head. It hurt him, and complications followed; the lymphatic glands became enlarged and inflamed, and the boy was forced to go to Paris for treatment. In the end, a serious operation was necessary, the scars of which ever after showed vividly on Lamarck's neck. So ended his soldiering.

5

If not a soldier, then what? Work, of some sort, was imperative. On four hundred francs, one did not live long in Paris. Lamarck sought out a garret, high up, with only the clouds for companions. A miserable hole, but it was there he began his study of the weather, since out of his small window the clouds only were visible.

But he could not live by the study of meteorology. So he got a job in a bank, stuck at it day after day, dreaming, however, of other things. Among them of medicine. Music, too, was alluring. But an older brother, wise in the ways of the world, took that nonsense out of his head and settled him in the way of learning to be a doctor.

For four years Lamarck studied medicine—only to decide at last that he didn't want to be a doctor. But

those were not four wasted years; they laid a solid foundation for the work in science soon to begin.

6

Jean Jacques Rousseau was, at that moment, the idol of France. One day Lamarck, wandering through the botanical garden, met Rousseau. It is not likely that Rousseau realized that he was in the presence of a greater than himself; but at any rate he saw a kindred spirit, warmed to the young man, and friendship grew up between them.

This was important to Lamarck. Always he had edged toward science. Rousseau swept him into the study for which he was most fitted. From that hour Lamarck was a scientist. No more of doctoring, no more music, no more of being a bank clerk. Henceforth science held him for every minute of his life.

So this young man of twenty-four turned his war fever into a passion for botany. For ten years he labored at this science. No one knows how he lived. How he worked all the world knows. And at the end of those ten years he put six months of desperate labor into his "French Flora." All he had at that time he gave to that book.

"French Flora" brought him little cash, but much recognition—and some friends. Among them Buffon—the great voice among French scientists. "Travel with my son," said Buffon to Lamarck. "Take him to the ends of the earth and show him the ways of life." Lamarck did so, going not only as companion to young Buffon but also as royal botanist. Back to Paris he sent plants and seeds, animals and minerals. He enriched the museum, but when he returned France had little with which to reward him.

## 7

There was of course a small position as keeper of the herbarium that a kindly government could give him. Salary, 1,000 francs a year.

Somehow, in the midst of all this, Lamarck had found time to fall in love, court and marry. His wife remains a shadow; never once does she come forward. There is no complaint of her, at any rate, voiced by Lamarck. But of all great men, Lamarck wrote of himself least. There were children, six of them; and there were poverty and distress, always. But there was no whining and no grumbling. There was just work and a steady belief in himself and a dogged endurance.

His appointment as keeper of the herbarium came in 1779. Ten years later, on the eve of the cataclysm, he was receiving the fine salary of 1,800 francs! So was genius appreciated at the moment when France was rushing into revolution. However, salary was of no importance to this digger after facts. Only when a hard-pressed government, facing bankruptcy, cut right and left in an effort to save pennies and neatly slashed off the keeper of the herbarium, did Lamarck raise his voice in protest. He called the attention of the assembly to the value of the work he was doing, and his place was kept for him. Even poverty could not spare this man.

All this time a world was falling to pieces around Lamarck, and he heard it not. Nor did any of the destructive bits land near him. Others were smashed, but Lamarck rode the storm, scarcely conscious that a storm raged. Through all of this he was a botanist, and nothing else. For twenty-five years his interest was all in plants. Not once, apparently, did it occur to him that his real work might lie somewhere else.

8

When Louis XVI passed, the Royal Gardens passed with him, and in their place arose the National Museum. In this new order of things, Lamarck, the botanist, was whisked over into Lamarck the zoologist, and he had at last found his life's work.

It took the French government only a few minutes to make Lamarck a zoologist, but it took Lamarck ten hard years to finish making himself one. From 1794 to 1803 Lamarck kept his mouth shut—and lived with his invertebrates. After that long silence, he spoke. And his first words were of the science into which he had been forced:

"These lowest orders of animals show us much better than the higher, the true course of Nature and the means that she has used to give existence to all living things."

Note that phrase, "the means that she has used." This was a faint hint of the blast that was to come.

9

Lamarck, instinctively, was a fundamentalist. He went into science with no theory to prove. All he wanted was to find out what was going on. He fitted in nicely with the average trend of thought in France. Almost everybody who was anybody believed in the immutability of the species. This idea, of course, was the thoughtless offspring of the special-creation theory. There is no reason to suppose that Lamarck had choked on that tenet. Probably a doubt of it hadn't entered his head at the time he gave up botany and began to study animals.

What made Lamarck change his mind? It's no use saying evolution was in the air, because that tells noth-

ing. Buffon was only partly an evolutionist. True, over in England Erasmus Darwin was vaguely theorizing, but more than two-thirds likely Lamarck never even heard of Erasmus—much less read anything of his.

Out of what he took his hypothesis doesn't matter. The fact is that suddenly, abruptly, he stepped forth as an evolutionist.

"Neither man nor anything else in the world is the result of special creation," said Lamarck. "That belief is childish, fit only for a primitive people. Theologians count time as 4,004 years from Adam to Christ, fixing thus neatly the age of the world. Reading these fossils and the stones in which they are found, I count the age of the world in thousands and thousands of years. What is time to Nature, that gigantic force which has no clocks? Read, you, the stones and the messages in the running waters that have worn and changed this earth.

"And throw away that silly notion of cataclysms, as of a violently wrenched earth or destructive floods. These changes of which I write came slowly, imperceptibly, a tiny bit at a time."

10

Lamarck was laughed at, mocked, distorted. Even today foolish people refuse to take the trouble to find out what it was Lamarck taught. And today, as data pile up, science is elbowing closer and closer to Lamarck's theory.

Ignorant ones say that Lamarck taught that animals, for instance, got eyes because they *willed* to see. But he never taught anything remotely resembling that nonsense.

But, cry the wise ones, who hate this brilliant Frenchman, he taught the inheritance of acquired

characteristics. Yes; but he taught it in a highly modified sense as coming about by the slowest process of indirection. It was not he who cut off the tails of mice in an effort to breed them tailless.

Time and changing environment were the tools in Nature's hands. He certainly never used those phrases "natural selection" and "the survival of the fittest," but here is his own favorite example:

How did the giraffe get his long neck? Imagine a slowly changing condition that forced this animal to feed on the leaves of trees or starve. Give centuries and centuries and centuries to this change. All the time the branches are getting farther away. What giraffe will survive? Naturally the long-necked fellow. Will it be surprising if his descendants run to long necks? Don't you every day hear of one who belongs to a long-lived family?

If your father and mother and your grandfathers and grandmothers each lived to be ninety, haven't you a better expectation of living to be eighty, say, than one whose ancestors have not been able to struggle through the dangerous fifties?

That's exactly what Lamarck said about his giraffe. He complicated it a bit by talking about the flow of fluids. If, he said, the giraffe stretches his neck to get food, he'll cause vital fluids to flow to the neck, and as a result it will grow in the direction in which it is used.

This, in a nutshell, is the famous Lamarckian theory. There was, you see, no "will" about it, and Lamarck never once used the word heredity. Nature and time, use and disuse—these were the ingredients in his famous pudding. Mendel had not yet lived, and the chain of fossils was not so nearly complete as it is today. It was not so much data as inspiration that gave Lamarck

to see the long, slowly unfolding road that led into the cloud-wrapped past.

11

To realize how far Lamarck was ahead of his time note this:

Many scientists of that day doubted the records of fossils and did not believe they were the stone images of animals that had once lived.

Spontaneous generation, the birth of animals without parents, was widely believed. Lamarck himself never grew away from it, and the notion prevailed until Pasteur, with the help of others, finally destroyed it.

The theory of special creation was universally held. When Lamarck denied it, he was branded as an atheist.

The ice ages in the history of the earth were unheard of, and people generally believed that it was something less than six thousand years since God with his own hands fashioned this world and turned out the animals. One of the arguments used against Lamarck's evolution theory was that the animals living in Egypt were exactly like their ancestors of two thousand years ago.

Is it any wonder, then, that Lamarck's theory was condemned and ridiculed and put safely away from the sight of all decent men? More than one sturdy church member sighed for the good old days of the Inquisition!

12

Through all of this Lamarck went his way and took no backward step. The boy who made himself an officer, and refused to retreat in the face of destruction, certainly was father to this man.

Stranger life no genius in revolt ever lived. Famous

at twenty-four, Lamarck was never enriched by his reputation. As with Kepler, poverty was his only chum. And, like Kepler, he carried on, and no whining came from him. Pain and afflictions visited him, but in his writings you will find no mention of his personal losses. Four times he was married and four times he was left a widower. Three of his children died, and the others, with the exception of one daughter, passed into oblivion, and history names them not.

But Cornelie, after a hundred years, still shines brightly at the side of her great father. True, she is limned against suffering, but she stands there serene, patient, enduring—a symbol of love and sacrifice.

Time had slipped by with Lamarck, and the energy that seemed inexhaustible had all but spent itself. More than sixty years separate him from that home in Picardy and the morning when he set out to be a soldier. Sixty years of digging for that small grain of truth which can alone brighten the life of the scientist.

This man's life, like that of Galileo, was fated to end in darkness. All of those small things with which he had busied himself passed forever. At the National Museum another took his place. Not his, now, to worry over the illness of an elephant, over the breeding of goats, the appearance of a young bull, the teething of lion cubs, the dispatch of duplicate specimens to the country towns. These intimate chores fell to other hands. Lamarck was blind.

## 13

Did his work therefore end? On the contrary, he was ceaselessly laboring at his greatest book, "The Invertebrates." His plan was to force a double supply of hours out of every day. Like Galileo, his mind was still grinding. He works. And Cornelie works.

The lodging of blind father and attentive daughter was not luxurious—shabby rather. There was little supply of ready money; only enough for the simple needs of two. No matter; at worst there was enough for food and shelter. A philosopher, fighting to finish his task, asks no more.

No one visited this home. And Lamarck went nowhere, except to the meetings of the professors of the museum. There his attendance was regular. To that board he presented the volumes of his "Invertebrates," as they appeared year after year.

Yet abandoned thus, forgotten by those who flocked to listen to the brilliant Cuvier, Lamarck was not unhappy, at least not desperate. He had the affectionate assistance of one person and he had great thoughts buzzing in that sightless head of his.

Do not, therefore, approach his dwelling in a spirit of condescension. A greater than this man will not, for a long time, move painfully across this world.

Stand here then—happily invisible both to the blind and the seeing, and consider this father and this daughter.

14

The woman is no longer young. How has she lived! Ask those lines around her eyes and on her brow—lines not drawn by time. The hair could so easily be beautiful; it has lost its glow. The face, were it touched with color and fuller in the cheeks, would bring the light to your eye. But she is not beautiful, unless it be the beauty of tears suppressed and pain endured. The eyes are large and they are sad. The age-old suffering of all time is in them.

And what of him whose universe is shrunk to this narrow room? He sits erect in a straight-backed chair,

facing the window. The lines in that old face are deep and cruel, but they have etched no bitterness, and they cannot hide his natural animation. The lids are closed over his useless eyes, and above them the heavy, arched eyebrows are white.

Cornelie listens, writing rapidly, while Lamarck dictates. They are at work on the last volume of "The Invertebrates"—the last chapter of a man's life.

15

Until July 11, 1828, he was regular in attendance at the meetings of the board of professors. After that date Lamarck was seen no more. No one knows how he lived during the eighteen months left to him. With what did he busy himself? What were the thoughts in that slowly bowing head? No further word came out from him.

Cornelie did not fail him. So much stands clear, testifying to the strength of a woman's heart. One gathers she did not during that time leave him for a moment. If her father was too weak to go out-of-doors, neither did she go out-of-doors. And the time came when he had no strength for even the shortest excursion. So they two shut themselves up in that blind house and forgot that the world was sunlighted.

Living in this frightful seclusion, the end of 1829 drew near.

On December 18, Lamarck solved the last great mystery. . . .

16

Cornelie, her work well done, could go out-of-doors now—and be overcome by the fresh air to which she had for long been unaccustomed. Hard for her to pick up the threads of this new life; too late to be a wife

and mother; too late for any real joy to bubble out of her heart. Anxiety was still with her since the question how to get bread remained to be answered. Fortunately the board of professors could help along that line, and did. She was set at work pasting dried plants —salary one thousand francs per year!

Ending thus in blindness and a kind of mysterious obscurity, Lamarck was forced into a certain publicity by his death. There were eulogies pronounced. One by Latreille, in the name of the Academy of Sciences. One by Geoffroy St. Hilaire in the name of that same board of professors of the museum. One by Cuvier on his own account, read and published, tending, in the main, to eulogize Cuvier—as a subject more interesting than a dead Lamarck. Cuvier also passed and had his eulogies and went his way into the shadows.

But that thing of evolution which Lamarck sent storming into the world, opposed by Cuvier among others, has not passed, has grown big with meaning for all men, has woven the shroud for the superstition called special creation and has enriched and ennobled man's idea of his God.

*Chapter Twenty-two*

## FARADAY

RUB amber and something happens. It will attract pith balls and the like. The ancients knew this and played with it as with a toy. The loadstone will attract metals. That also was an old-time knowledge. Amusing mysteries, these things, but hardly worth the serious study of a philosopher—and in those days philosophers were nothing if not serious.

Centuries rumbled away. The loadstone still did its trick, and the mariners' compass came into use. There things stopped until William Gilbert, English and curious-minded, began to study the loadstone and amber in the last half of the sixteenth century. His conclusions are set down in his book "The Magnet," written in Latin, of which English translations have been made. He didn't get far, according to present standards, but he systematized what knowledge there was on the subject, and he contributed one or two startling ideas of his own. The earth, he said, is nothing but a huge magnet, which accounts for the action of the needle in the compass.

Robert Boyle, born in 1627, twenty-four years after Gilbert's death, delved into almost every line of science and so wrote a book on "The Origin of Electricity." As to "origin" he didn't know much, but he tossed off one new idea that helped later investigators; the attraction between rubbed amber and the pith ball is mutual.

Otto von Guericke, a German born in 1602, gave the world something brand-new. He made the first machine man ever saw for generating electricity. It was a simple thing, merely a ball of sulphur revolving under friction, but it worked. Of course it wasn't worth a rap except to play with, but just the same it was a generating machine and stands as a tribute to von Guericke's genius.

The Frenchman, C. F. de C. du Fay, whose short life, ending in 1739, was full of activity, discovered that the electricity caused by rubbing amber and that caused by rubbing glass were not alike. This naturally raised the question, how many kinds of electricity are there? For a hundred years this remained unanswered. But du Fay went further and learned that like electric charges repel each other and unlike attract. A comfortable amount of work on a hard problem.

2

Thus far in the history of the world electricity had been a flighty thing. It was there for a jiffy after glass was rubbed with silk or amber with flannel—and then it was gone. E. C. von Kleist, of Pomerania, wondered about this and mulled over it and made an experiment. It succeeded, and in 1745 the first Leyden jar was charged. Long afterwards this Leyden jar was going to prove helpful to wireless telegraphy.

But von Kleist wasn't the only one who was thinking, and the very next year the jar was made at the university of Leyden, whence its name. Every scientist in the world was immediately interested in this new toy. Electricity could be stored up, held in the glass plates in the jar, and discharged at will.

Ben Franklin was fascinated with the thing. But a single jar wasn't enough for his large way of doing

things, and he showed the world how to hook the jars up in series, the outside coating on one jar being connected with the inside coating of another. This gave him a chance to store up a lot of electricity and get a bigger flash and a harder rap on the knuckles when his hand discharged it.

This, you see, was a big jump. Now experiments could be made that were formerly impossible. It occurred to William Watson, in England, that this electricity might be carried away from the jar over a wire. He sent it along two miles of wire and was amazed to find that it went the distance in no time at all. There was the first step toward the telegraph and cables and wireless.

3

How to get electricity in large quantity? That was the problem. At this point scientists were stopped. And then came Allesandro Volta. This Italian knew what he wanted, and he went to work deliberately to get it, and out of his effort came the Voltaic pile. Take disks of copper and zinc, alternately; between them put cloths soaked in a dilute acid; connect the end plates, and there you have it. Gigantic Voltaic piles, reaching as many as two thousand plates were made. From this could be obtained a current sufficient to operate an arc-light, as was proved by Humphry Davy.

There was your electricity in quantity, strong enough for any sensible experiment. Of course so big a Voltaic pile cost a lot of money; and electricity generated in this manner was priceless, and no commercial use could be made of it. But men were edging toward the discovery that would make the thing practical.

Hans Christian Oersted, of the University of Copenhagen, ran a current through a wire and induced a

movement in a neighboring magnet. The needle would turn one way if below the wire, and the other if above it. Was there some relation between magnetism and electricity?

Humphry Davy answered that question in 1820, and showed how iron and steel can be magnetized by passing an electric current around them.

With these data the stage was set for great things —if only the right man would appear. Singular how repeatedly in history, when the man is needed, he appears. He appeared now, ready to open the door to the electrical age.

4

A quiet, slight, boyish bookbinder was plying his trade at No. 2 Blandford Street, London. Michael Faraday was his name, and he had been for seven years learning his business under the direction of George Riebau. He had learned other things besides. There was in this boy's head an urge, and he satisfied it by reading the books he bound.

Michael, born in 1791, had little chance to get an education. His father was a blacksmith and made his living in the heat of his forge. He gave his family food and some show of bodily comfort—but he had no shillings to waste on luxury. Schools came under that head. What need of learning to work at a trade? That his boy Michael might climb into something better than a trade never entered James Faraday's head. In England, a century ago, one stuck to the class of society to which one was born. Michael was born to work with his hands.

An active, laughing boy was this Michael when at thirteen years of age he went as apprentice to Riebau to learn bookbinding. Riebau took him for a year on

trial as errand boy and what-not around the place. At this job Michael was satisfactory, and so he was signed on for seven years.

Diligent and good-natured, Michael wormed his way into the heart of old Riebau. What if an hour were wasted while the boy read? He did his work well, and one had a right to pick up crumbs of wisdom. "Go ahead, Michael," said Riebau, "read all you please. You'll be no worse a bookbinder for knowing the insides as well as the outsides of books."

But this was strange fodder for a boy, unschooled and woefully ignorant, to cram into himself. A book by Watts on "The Mind" first made him think. Then in an encyclopedia he was binding he ran across an article on electricity. What did Michael Faraday know of electricity when he turned to that page and began reading? Nothing.

Viewed in the light of today, that article told him little. That, in itself, may have been an incentive. Here was a subject that struck sparks from his imagination —and about which no one knew anything. So much the better. He could start even with the field. To pick up the hints dropped by Franklin, von Kleist, Watson, and others would be a small task. "It will not," thought Michael, "take me long to learn all that is now known about this strange electricity because not much is known."

5

Those seven years of apprenticeship swept by. Michael, with deft hands, could bind a book with the best of them. Sometime during the years a copy of "Experiments in Chemistry" had come his way. That book he devoured. With what bits of money he could save, he bought himself cheap and simple apparatus,

set to work doing those experiments, training his mind, developing a technique.

The farther he went along that road the more interesting it became, and the more vivid was his curiosity. No book of science could get away from him. It was a case of genius making a road for itself. Poverty, work, ignorance, were only obstacles around or over or through or under which his spirit would find a way. How he laughed as an experiment came out exactly right! Always in this man there was a great fund of laughing enthusiasm, a dashing audacity, hiding behind an honest modesty. Without this audacity he probably would have spent his life as a bookbinder, and the world would never have worn a path to his door.

What could a bookbinder apprentice want with a seat in the gallery at the Royal Institution while Sir Humphry Davy lectured? But this boy wanted that seat, and he had the effrontery to mention his desire to one of Riebau's customers. It was unheard of, it was preposterous, but the customer was tolerant. It would cost him a few shillings. But to what better use could he put his change? Buying immortality for the price of four tickets to lectures on science!

Michael went to those lectures. He listened, he made notes, he understood what was said. Later, in his shabby little room at 18 Weymouth Street, he wrote out his notes, elaborating Davy's lectures, proving in this way that he knew what was what and had got the meat out of Davy's words. Did he realize, as he sat laboriously writing, writing, until his arm ached and his head whirled, that he was on the verge of a great change? Who ever realizes a thing of that sort?

Yet a change was needed. This bookbinding was not all roses. Riebau had been all right, but this De La Roche, of Kings Street, for whom he went to work as

a full-fledged craftsman, was not like Riebau. Hot-headed and emotional, he poured out his words and did his thinking afterwards. For him one bound books and confined one's interest to the outside only. No reading of scientific articles in this man's shop. Get that nonsense out of your head. Michael had been spoiled by Riebau, and this new, harsh task-master constantly rubbed him the wrong way. Also he was now learning things about business and the way it was carried on—and the more he learned, the more he felt it was not for him.

But how to get away from it? There was the call of science, but how could one make one's living at science? Michael was no expert, he had no degree, he knew nothing of mathematics. He had no friends, that is to say, no influence. He was just a poverty-stricken genius, made into a bookbinder, and he was fast learning to hate his trade.

His rare audacity, hidden behind honest modesty, nerved him. He sat down and wrote the great Davy a letter, enclosing the notes of the lectures as "proof of my earnestness." Then he waited, uncertain—more than two-thirds convinced he would never even hear from Davy. Davy was the most popular lecturer in London, one of the greatest scientists in the world. How could he take time to answer a letter from a poor bookbinder?

But Davy answered, kindly, and made an appointment for a meeting. By that act he made his most astounding discovery: he found Michael Faraday.

6

Precocious Davy had come early to fame. Laughing-gas was his introduction to chemists. He was twenty-one years old, connected with the Medical Pneumatic Institution at Bristol, when he discovered that nitrous

oxid could be inhaled with no bad after effects. This, coupled with a book on "Researches, Chemical and Philosophical," published the next year, sent his name sky-high. Count Rumford engaged him as lecturer on chemistry at his newly organized Royal Institution at London.

When he swooped down on London, Davy was the original flaming youth. He wasn't a big, handsome fellow, but he was dynamic and he had a fine "stage" presence. He could make people hang on his words—and did. His lectures became the rage—about a thousand could be depended upon to come regularly to hear him.

There is more than one version of his meeting with Faraday; one says that he ran into Michael in the bookbinding establishment and puffed up when he saw his own lectures on a shelf, all neatly bound. That's probably just a story. More likely the truth is that Faraday, as stated, wrote Davy before the two ever met, and that Davy wrote back, "Come and see me."

Accordingly it was late in January or early in February, 1813, that Faraday marched off to the Royal Institution. He trembled as he waited for the great man to come into the anteroom. Then Faraday, hardly knowing what to say, stammered that he wanted work, voiced platitudes about the ethics and nobility of science and gave trade a bad reputation.

Davy smiled, cynically. "As to the superior moral feelings of philosophic men, I will leave you to the experience of a few years to set you right on that. My advice to you is, stick to bookbinding. Oh, well, if that trade offends your soul—" he went on to say he would do what he could, lend Michael books, keep an eye out for a chance in the institution. There was nothing at present. So ended that first meeting.

A month later, early in March, Michael and his mother, peering out into Weymouth Street, saw a grand coach from which a ramrod footman descended. Consternation was in Mrs. Faraday's eyes. The man was cōming to her door! True enough, and he left a note for Michael Faraday—a brief message, the echo of which still clicks busily around the world.

Davy wanted Michael Faraday to call at the Royal Institution the next morning! Guess whether Michael slept well that night, or was late for the interview next morning. Or whether he hesitated when Davy told him: "An assistant is needed in the laboratory at a salary of twenty-five shillings a week. If you are still desirous of changing your—" He was desirous, he was ready, instantly, to take up his new duties.

All the world, as it now sits reading by electric light or whirls across town in electric trains or warms itself before an electric heater, can rejoice in that decision and thank Humphry Davy for giving Michael Faraday a chance.

## 7

Where did Faraday learn chemistry? At no school and at the feet of no master. Where then? Out of the air, as plants get nitrogen. He absorbed it. It is not too much to say that he had a passion for the subject that amounted to an instinct.

When he joined Davy, Sir Humphry had been given the problem of inventing a safety-lamp for miners. A delicate business since thousands of lives were at stake. At once Faraday got to the crux of the thing, made brilliant suggestions, helped Davy win through. That was the work of no untrained amateur. Davy realized this, seems instantly to have sensed the power of his assistant.

Six months of work cemented this opinion and led to greater opportunity for Faraday. Davy was going abroad to catch up on science in Europe. His wife was going too. And why not Michael—as amanuensis? to write out Davy's notes—and look after details?

So it was decided, and for eighteen months Faraday was out of England. At the last minute he came near giving the trip up. He didn't want to be a valet.

Davy had himself been a Cornwall pauper, and he remained on the fringe of poverty until marriage brought him a rich wife. She seems to have been a haughty lady—perhaps because she was a distant connection of Sir Walter Scott. This insistance upon a valet as the outward and visible sign of a gentleman probably was her idea. Davy fell in with it, and by the time he was ready to start for Europe he had decided a valet was absolutely necessary to his happiness. But his English valet resolutely refused to brave the dangers of Dover Strait. Would Michael mind acting as valet until they reached Paris? Michael would. And said so. Davy fussed and fumed. The trip was on the point of being held up for the want of a slipper-chaser. Michael, eager to get to the Continent, yielded. "But only until we get to Paris." "Fine!" cried Davy. "You'll have little to do. Almost everything I do for myself."

But in Paris no valet was available—at least none satisfactory. Nor could one be had at Lyons, at Montpellier, at Genoa, at Florence, at Rome, "nor in all Italy," writes Faraday. "And I believe at last he did not wish to get one; and we are just the same now (five months after sailing) as we were when we left England."

There's a picture for you! The keenest student of electricity in the nineteenth century acting as valet,

body servant, to a proud and irritable man with a proud and silly wife! But at that time "she liked to show her authority and at first I found her extremely earnest in mortifying me," said Michael. And this "earnestness" led to an embarrassing situation in Geneva.

Continental scientists found Michael worth talking to, and it never occurred to them that he was socially inferior to Davy. Certainly such an idea did not come to Gaspard de la Rive, professor of pharmaceutical chemistry at the Academy of Geneva. Gaspard liked this young Michael, and when the Davys were guests at his home he assumed that they would all dine together. Lady Davy and Davy himself had other ideas and said so. De la Rive was shocked and told the Davys exactly what he thought of the whole business. That didn't help Michael, who dined, solitary, in a separate room.

There was a story tossed about Europe for a long time that Gaspard later gave a dinner in Faraday's honor. The honest historian is now obliged to strike out this dinner. Gaspard did not give it. That would have been too nearly perfect, and things seldom work that way. But it is true that during the rest of his life Gaspard corresponded with Faraday, and after his death his more famous son continued the letters.

8

Homeward bound, after eighteen months, and glad of it, Michael wrote to his mother from Brussels, carried away with the prospect of seeing her again: "Adieu, till I see you, dearest Mother. . . . This is the shortest and to me the sweetest letter I ever wrote you." What matter if this woman could barely read and write. She was his mother and he knew her strength and tenderness.

Immediately he returned to the Royal Institution—and had his wages raised to thirty shillings a week. Seven dollars and a half! And Michael was nearly twenty-four years old. Times have changed.

He and Davy finished up the miners' lamp, and the next year it went into use, underground. "Not perfectly safe under all conditions," admitted Faraday—and thus annoyed Davy, whose vanity got between him and the vision of an accident.

Michael had served one apprenticeship—he was now serving another. When the professors lectured, he was at hand with apparatus ready for an experiment. And he was always at Davy's elbow, soaking up whatever there was to be learned from him. He grew during those months, and stepped out on his own—joining the City Philosophical Society, whose high-sounding name covered the meeting of youngsters interested in science. Michael lectured for them—on chemistry, dealing out, second hand, what he had heard—contributing little original, but slowly finding himself, learning to talk, to perform experiments in the presence of an audience.

9

Women were nothing to this young man—only something to be avoided, something to be written against, as witness his diatribe in criticism of "falling in love." Nothing so silly as love could bother him. And it did not, while the years went by, and he learned chemistry and lectured to his C.P.S. and wrote for the Quarterly Journal of Science—and got his feet under him.

But no man whose heart is merry is safe in this world. Michael was twenty-nine, and might well think he was now able to pick his way among life's pitfalls.

He was religious and went regularly with his mother to the little Sandemanian church. And that brought about the fateful meeting. Sarah Barnard, daughter of a silversmith, was wise and clear-eyed and kindly. Michael saw her, and peace went out of his soul. There were no more verses scoffing at love. Instead he wrote to Sarah:

"You know me as well or better than I do myself. You know my weaknesses, my vanity, my whole mind. . . . Again and again I attempt to say what I feel, but I cannot."

He who scoffed has remained to pray; yes, and to become one of the world's great lovers. Forty-three years later he will be writing Sarah tender and passionate love letters. They were together for almost fifty years, and not for one moment did Faraday's love fade or turn aside. Against the fine glow of this steady adoration, Sarah stands as the image of the perfect wife. She never doubted, she never wavered, she never failed him. Always she "knew him better than he knew himself," and there was in her mind no worldliness, no envy, no greed. He refused opportunities to make a fortune; Sarah approved. He was bravely generous with his small earnings; she did not criticize. He withdrew, early, from all social life; she did not complain. For once, at least, in the history of the world a man and a woman met and, with their brains and with their hearts, understood each other. Thus proving, with quiet conclusiveness, that the thing is possible.

10

June 12, 1821, Michael and Sarah were married. Fame had not yet beckoned him; nor was there any assurance that the gesture would ever be made. It is likely no man ever lived who courted fame less. He

had his work to do; he wanted to keep his job, provide for his wife and mother and if possible pry out one or two of Nature's secrets. That was his unambitious, honest program. Steadily he went about carrying it out, helping Davy in the laboratory, assisting at the lectures, writing his small papers for scientific journals.

Unblinded by large dreams, he saw clearly whatever small thing came his way. For instance, when he heard that Oersted had deflected the magnetic needle by passing an electric current near it, Michael had a real thrill —and later got himself into a bit of a mess over it.

William Hyde Wollaston was a big name among English chemists. He was at this time, 1821, fifty-five years old and a recluse. He had mighty little confidence in anyone, even scientists, and his experiments were performed in secret, no one, under any circumstances, being permitted to enter his laboratory. This discovery of Oersted's, however, shocked him out of his shell, and he hurried down to the institution to talk to Davy about it. Some way the old gentleman had got the idea that if the pole of a magnet were brought close to a wire carrying a current, the wire ought to revolve around its own axis. He tried, in Davy's laboratory to make the wire do this small trick—and failed.

Most likely Faraday was hanging around and heard and saw what went on. There wasn't much to see. The thing wouldn't work, and Wollaston left in disgust. Maybe it'll work after all, thought Michael, and he tried it himself. On September 3, 1821, he saw, for the first time, the electric wire rotate around the magnet.

"There they go, there they go," he cried, dancing around his apparatus.

He repeated the experiment a good many times, and on Christmas day, 1821, made the wire move under the

influence of the earth's magnetism alone. Naturally Michael was delighted. He had done what other scientists had failed to do. Jubilantly he wrote out his pretty little experiment for the Quarterly Journal of Science, in which it appeared in October, 1821.

When Wollaston saw this paper he was convinced that his lack of faith in his fellow men was well founded. He was enraged. He said Faraday had tricked him, and insisted that credit, if any, should come to him. Michael denied this. He said, what was no more than the truth, that Wollaston had tried and failed, and that the discovery could hardly belong to a man who had been unable to make it. With the facts before them, Davy and others agreed with Faraday, and the matter was dropped—for a time.

Soon after this, Michael offended Davy's pride. In his spare moments Michael was working on the problem of turning gases into liquids. Following a suggestion of Davy's he heated hydrate of chlorin in a sealed test-tube and in this manner succeeded in liquefying chlorin. This was a big thing for the young chemist, and he prepared a paper on it for the Royal Society. Davy, of course, read this paper and stuck in a note showing what part he had taken in the experiment. Faraday made no objection, and the paper, as edited by Davy, was read to the society.

But—Davy was jealous. What business had this former bookbinder and valet to perform so startling an experiment right under the nose of his master—and take the credit for it? You and I would think Faraday was entitled to the credit; but for a long time Davy had been the bright particular scientific star in England, and it was not easy for him to admit that a rival was dimming his light.

11

Each of these misunderstandings bobbed up again in 1823. Faraday was proposed for membership in the Royal Society, of which Davy was president and Wollaston a member. Both of these men opposed his election. Wollaston proved reasonable. Michael went to him, told him exactly how he had happened to make the experiment with the electric wire and magnet, and Wollaston, accepting the explanation, put his seal on the candidate.

Not so Davy. He ordered Faraday to withdraw his name. Michael said he couldn't do that. Davy insisted that those who proposed the name should be asked to withdraw it. Michael was sure they would refuse to do so—and in the end he was proved right. Davy then said that he, as president, would throw the name out himself.

"I am sure Sir Humphry Davy will do whatever he thinks is for the good of the Royal Society," said Faraday.

How could one argue with a man like that? The name was proposed, and when the vote was taken there was but one blackball. No one knows who cast it, and it no longer matters. The valet had become a member of the Royal Society, and had a right to sit at the table with the best of them.

12

Faraday was developing slowly. He was now well past thirty, member of the Royal Society and director of the laboratory at the Royal Institution. He had made a couple of original researches of value, had learned to lecture and had made friends. His services were in demand as an expert by commercially minded

people who had scientific problems. At best, he was known to a limited circle as a likable and dependable chap, but was far from looming large in the eyes of the world.

One determination he came to—to be a scientist and nothing else. The expert business brought money, but it took time. He wished to give it up, and Sarah was willing. She had no expensive tastes—and there were no children. The salary at the institution was small—but it was enough; and he would have a chance to experiment, to learn, maybe, a thing or two as yet unknown to man.

So he made his decision, and there was no more expert work for him after 1830—or, at least, only that done for the government on lighthouses, a humane undertaking that enlisted Faraday's ready sympathy. Other kind of work outside his laboratory he never again accepted.

But the seven years from the time of his election to the Royal Society to 1830 were not spent in idleness. In 1824 he separated benzin from condensed oil-gas, calling it bicarburet of hydrogen. Many a big business has been built up around that benzin, which since Faraday showed the way has been produced in immense quantities. But Michael did not want, or get, any money out of his discovery.

Nor did he expect any cash returns when he gave his attention to glass making. The Royal Society brought this question up: Is it possible to make a perfect optical glass? The chemical problems involved in finding an answer to this question were put in Faraday's hand. For four years he worked at it and in four years he made a lot of glass. But he was never able to say "Yes," to the Society's question.

He succeeded in making glass that improved the

telescope—but it was not perfect. And at last he asked to be permitted to stop the work for a while, "that I may have the pleasure of working out my own thoughts on other subjects."

13

Davy, in 1820, magnetized a bit of soft iron by running a current of electricity around it. In 1822, Faraday wrote in his note book:

"Convert magnetism into electricity."

If electricity magnetizes, why won't magnetism electrify? That was the question he asked himself over and over. It was a logical deduction; but how could he bring it about? Most desirable, too, since electricity is a valuable commodity and may be useful in a thousand ways if it only can be produced in quantity at a low cost. Voltaic piles cost a great deal of money and there was a limit to the amount and strength of the current. Obviously a readier and cheaper way was of first importance.

There is no lack of magnetism, since the world is itself a gigantic magnet. But from this world-wide magnetism to electricity—what a step! And it must be taken in the dark.

Michael stumbled this way and that, having nothing to guide him, nothing to lean on. But he had the instinct of the homing pigeon, of the lost dog. Here is an action; what then is the reaction? Here is energy, and dimly, long before the law was set down in words, he understood that no energy can be lost. These were vague landmarks, but they might lead a close observer —somewhere.

In his pocket Faraday carried a bit of iron around which copper wire was wound. If he ran a current through that wire, the iron became a magnet. All the

scientific world had known that fact for ten years. But how could he, with the magnet, set up a current in the wire?

A hundred years ago there was in all the world no dynamo, no electric lights, no motors. Not one cent was invested in electrical enterprises. Electricity was a plaything in the laboratory. Science knew it as nature's most illusive mystery, but to the business man, the soldier, the lawyer, the doctor, the editor, the author, the farmer, the word "electricity" was just a word. It had not the slightest connection with every-day life. The fools who puttered around in dusty rooms littered with test-tubes and scraps of iron and bits of wire and dirty bottles might find it an interesting plaything, but no hard-headed business man would waste his time bothering with it.

In the fall of 1831 reports came to Faraday from the continent that something in the way of a current had been produced by a magnet. But within a year the report was withdrawn; it was a mistake due to optimistic observation. The situation seemed hopeless; he had come to the end of the road.

14

How could one make headway against this mystery? He inserted a magnet into a coil of copper wire without result. He brought a wire carrying a current close to an unelectrified wire. He tried a larger magnet. He brought the wire into all sorts of complicated relationships to the magnet. And still no trace of electricity appeared in the wire.

Is the thing then impossible? Something deep in Michael's mind cries out, "No." There is a relationship. Why does the iron become magnetized when a current passes around it? And lose its magnetism the

instant the current is shut off? He doesn't know—no one knows. But it proves there is some subtle and illusive link between the two phenomena. What effect magnetism has on electricity does not appear. But there must be an effect. He can only keep on trying.

Accident, or fate, favors the man who won't be beaten. On October 17, 1831, he got hold of a cylindrical bar magnet, three-quarters of an inch thick, eight and one-half inches long. He wound two hundred and twenty feet of copper wire into a hollow cylinder. To this wire he attached a galvanometer. There was no current in the wire.

He brought one end of the magnet close to the wire. There was no movement of the needle of the galvanometer. Suddenly he thrust the magnet all the way into the coil of wire. The needle moved. Quickly he drew the magnet out. Again the needle moved.

A current of electricity had been formed by induction.

Why had all of his other experiments failed? How did this successful experiment differ from the others? A great light shone about him: always before both magnet and wire had been stationary. He had discovered the secret. Movement was needed.

He was forty years old but he danced around his laboratory like a boy. Again and again he repeated the experiment, and each time the needle jiggled back and forth. It was no accident—due to no outside influences. The thing was done.

But the reaction came. After all, what he had done so far was nothing, if it ended with merely a slightly agitated needle. What had he really proved? Was this thing that made his needle dance the same thing that came from the Voltaic pile? He must have something larger and more emphatic than a nervous needle, so

twelve days later he had a copper disc with a handle fitted to it, borrowed a big horseshoe magnet from the Royal Society. Between the poles of this he revolved his copper disc which was connected with a galvanometer. The needle moved as the disc turned.

But why should motion be necessary? He knit his heavy brows over that and at last the answer came to him: Because the metal must cut the "magnetic curves," that is, the "lines of magnetic force."

From this he passed rapidly to experiments with electrified and unelectrified wires. He increased the power of his battery and to the wire carrying the secondary or induced current, he attached minute pencils of charcoal. Then as he made and broke his current, a tiny spark leaped between the bits of charcoal.

And, behold, the embryo of the electric light!

To Faraday that barely visible flash was like the rising of a new sun. It proved to him that what he induced in the second wire really was electricity.

15

But all of this only whetted his appetite. He would go ahead and make himself a new electrical machine. Naturally it would be simple, but ancestor to a host of complicated and involved descendants. He set the edge of a copper disc between the poles of a permanent magnet. Strips of copper and lead, to serve as collectors, were placed in contact with the edge of the disc. Connection was made with a galvanometer. When the disc was rotated the needle was deflected. Here, then, was produced, from the magnet, a steady current of electricity.

Faraday did not patent his machine. He did not hug his discovery to him until he was sure he was protected at all points from theft and infringement. Nor did he

feel that he was entitled to coin his genius into cash. In a paper read before the Royal Society, he told all about his discovery and his experiments. He held back nothing. He had uncovered an inexhaustible gold mine and he turned his back upon it, and his words indicate that he did this deliberately:

"I have rather been desirous of discovering new facts and relations dependent on magneto-electric induction, than of exalting the force of those already obtained; being assured that the latter would find their full development hereafter."

All the electric apparatus that we use so casually was lying hidden in Faraday's discoveries and in the simple machines that he built. He had done what he set out to do. He had tapped the universal source of electricity—and could leave everything else to the men whose ideals were commercial.

Faraday's work on electricity could not end at this point. He had made his major discovery but he went farther, attacking whatever problems arose. There was much discussion as to the kinds of electricity. Davy and others were trying to classify electricity according to sources, and wasting a lot of time talking about a thing that needed only wise experiment to clarify it.

So Faraday set about testing electricity from every known source. In each case it behaved the same—manifested itself by the same phenomena. He therefore could arrive at but one conclusion which he set down thus:

"Electricity, whatever may be its source, is identical in its nature."

What about conduction? That, also, was a blind subject, hotly debated. Michael was not much given to talk; his idea was to prove the thing in the laboratory and let the others argue. For instance: water, he knew,

was a conductor, and to his amazement he discovered that ice was a non-conductor. This led him farther until he formulated the rule that fusible solids are conductors when liquefied and non-conductors when congealed. Metals and fats, he found, were exceptions, the former being always conductors and the latter never.

He wanted to measure this electric current with which he was playing. It was present and its power could be tested in various ways, but how standardize its measurement? He knew by experiment that water is decomposed by an electric current and that gas is evolved during the process. The power of the current can be expressed in terms of the amount of gas evolved from the water through which the current passes. He decided this would do—and the voltameter came into existence.

"If the electrical power which holds the elements of a grain of water in combination, could be thrown into the condition of a current, it would exactly equal the current required for the separation of that grain of water into its elements."

Faraday wrote that sentence in 1834 and hiding in it are two theories, formulated long after his time. It hints, somewhat vaguely, at the electron, and it is almost a flat statement of the conservation of energy.

16

Work in the laboratory, lectures afternoons and evenings, home to Sarah, and all the time thinking, thinking, brooding over some obscure problem. Years of this grind for Michael. And all the time he was troubled with a bad memory which grew worse and which he complained of while yet a young man. He had no social life, and he and Sarah went nowhere except

on Sunday to the little Sandemanian church. Human nature could not stand such unrelieved drudgery. The break came and for four years he was able to do almost no work.

During this period he hated talk and wrote emphatically that he could not stand it, "being at present rather weak in the head." When a man is unable to work what can he do with talk? It became, to Faraday, only a burden and a weariness.

This leading scientist found strange amusements when sickness barred him from the laboratory. Chiefly he went to the Zoological Garden to watch the animals. They delighted him and he took a boyish and wholly unscientific interest in their antics. Acrobats, tumblers, dwarfs and giants were next in favor. A Punch and Judy show would send him into peals of laughter. He and Sarah went to Switzerland and there too his chief interests were remote from the subject that had engrossed him. Waterfalls, avalanches, cows and sheep with their herders, and the straggling, indifferent goats, pleased him most of all. The blacksmith shops always attracted him.

All the world delighted to honor him. Universities hurled degrees at him. He put these signs of distinction away and was never known to exhibit them even to his closest friends. It is easy to believe that to this man such things were baubles. Indeed, he was kept rather busy declining honors. He refused the presidency of the Royal Society; he refused a professorship in the London University; he refused the presidency of the Royal Institution; he refused to be knighted. He accepted a small pension on the civil list and would take nothing more from the hands of the state.

Surely here was one who loved his work and got his greatest joy out of a "beautiful experiment."

## 17

This blacksmith's son, this bookbinder, this boy who had never entered a university as a student, had found a place in the sun. Did this change him? Was this husband, growing old at Sarah's side, very different from the youth she had married? Then he had belonged to an obscure religious body; he had lived frugally in his rooms at the Royal Institution; he had dreamed and doubted and hoped; he had gone gropingly, humbly, into the presence of nature's mysteries.

He changed very little. His hair turned white, lines came in his face and his bad memory grew worse, but his heart remained forever young. He and Sarah still lived modestly at the Royal Institution. Sundays they went on foot to the same Sandemanian church of which Michael was an elder. Still he entered his workshop reverently and doubts and fears possessed him.

He stayed young for his enthusiasm never faded. A visiting scientist, Plucker, of Bonn, showed him an experiment, which delighted him so much that he danced around the room shouting, "Oh, if one could always live with it!"

## 18

But he could not always live with it. Time strains things down too fine. Relentlessly strength was dragged out of him. His memory was gone or fast going. Today he does not remember the experiment he made yesterday. Work must be given up, then, and the laboratory knew him no more. He was conscious of his weakness and he wrote to his niece:

"My worldly faculties are slipping away day by day. Happy is it for all of us that the true good lies not in them."

A friend said to him, "You cannot mean that you have outlived your wisdom."

"Something like it," Faraday answered, "for my memory is gone. Now I must content myself with giving my lectures to children."

Even these, at last, came to an end and shortly afterwards all lecturing ceased. On June 20, 1862, he gave his last lecture. For five more years he lingered between living and dying, growing weaker, until at last he could scarcely move. Sarah was with him constantly, as she had been for fifty years. On August 25, 1867, he passed peacefully into a sleep from which he did not again awaken in this life.

His work was done. He had made possible this age of electricity in which we live, all the marvels it brings us and all those which it may, in the next centuries, bring to our children. All of it leads back in a straight line to the genius and the industry of Michael Faraday.

*Chapter Twenty-three*

# PASTEUR

STAR gazers mapped the heavens and seized subtle laws. Chemists—Cavendish, Priestley, Black, attacked the elements and directed thought toward the channels in which it still flows. Buffon, Linné, Lamarck, delved into the secrets of natural history. Thus, science was broadening, deepening, sweeping ahead on a wide front.

But one wing dragged, most important of all; without it no real victory was possible. Human health was still ignored; or at best, left to quacks and priests and barbers. Why were people so indifferent to disease? God knows, there was plenty of it. Time after time Europe was plague-swept and the streets of the big cities were filled with dead.

No use worrying about all this, said Ignorance. The Black Death was a visitation, one of the crosses humanity had to bear. Better not fly in the face of Providence by trying any new-fangled ideas of cure and prevention. Superstition walked arm in arm with death and no one thought of calling them twins.

Vesalius, Servetus, Harvey, seemed to have lived in vain. Their successors for the most part were quacks—men and women who grew fat and prosperous by trading on fear and gullibility. The frightened and foolish paid and hoped and died; the state did not interfere and no cleansing fire came down from heaven.

2

Schools of medicine flourished—each sillier than the other and each enjoying mushroom fame. There was, for instance, John Brown who held that living tissues were "excitable," and disease, therefore, merely a matter of too much, or not enough excitement. Having decided which was which in the case of a patient, he gave opium to depress and alcohol to stir up—and let it go at that. Feeling that his own excitability was low he swigged quantities of wine and when under this treatment he grew too excited, he quieted himself with opium. A combination of the two finally killed him.

As one more example, and that enough, take Georg Ernst Stahl. He argued that a "sensitive soul" was the important thing in life. The body, he said, was just a machine; therefore anatomy and chemistry were useless to the doctor and he spurned both of them. Disease, to him, was misdirected effort on the part of the soul. The business of the physician was to teach the soul to behave itself. This could be done best by the use of "secret" remedies. When these failed he'd drain off quantities of blood. Some of his patients lived; most of them died—without in the least disturbing Stahl. He had followers and imitators and his foolishness died hard.

3

In the eighteenth century blood letting was at its height. Surgery was in the hands of barbers; there were no dentists and obstetrics was turned over to old women. More than half of those operated on died of blood poisoning. A baby had about one chance in eight of living through the first year. In six years—from

1771 to 1777—31,951 babies were admitted to the Paris Foundling Hospital and 25,467 of them died.

In Dublin conditions were even worse. Out of 10,272 children in its Foundling Asylum, just 45 lived.

Rousseau was not being merely sentimental when he told French mothers to nurse their own babies. He was being scientific. The baby feeding at its mother's breast had a fighting chance to live.

There were hospitals, of course, but they were not the nice, satisfactory places hospitals are today. Only severe cases went into them—and few came out alive. The dread of hospitals sometimes encountered even now is a left-over fear from the time when they were death houses and no sane person went into one without making his will and telling his friends good-by.

Hôtel Dieu at Paris had twelve hundred beds and it was not unusual to find six patients in one bed—from four to six was the rule. If the beds were all occupied, a heap of straw in one of the halls would do, and these halls sometimes contained as many as eight hundred miserable wretches. Tenon's Memoirs on the Hospitals of Paris, describes conditions even more horrible. A copy of that book together with the latest report from any big modern hospital will quiet many criticisms of science and doctors.

4

The treatment of the insane makes one lose confidence in human nature. Harmless lunatics ran at large, propagating as opportunity offered. Violent cases were put in chains in cold, damp cells. They were beaten, or strangled with cold water and dosed with drugs. Opium, camphor and belladonna were the favorites—especially belladonna. If that failed the case was hope-

less and no more was done about it. Mustard plasters and Spanish fly were also freely used. Surely anyone with a glimmer of reason would play sane to escape such treatment.

In the midst of this barbarity the Friends get a touch of credit. The Quaker Retreat, founded by William Tuke in 1794 at York, marks the birth of the idea that the insane should be treated like human beings—not like wild beasts.

The blind fared no better, or worse since they were more sensitive than the insane. Europe was overrun with them and not the slightest provision was made by state or city for their care. Hence there were hordes of blind beggars who fought and caused riots in their efforts to clutch alms.

Denis Diderot in 1749, looked out upon the struggling blind of Paris and got an idea. Invent a system, he said; teach these afflicted ones to read, train them to some useful occupation. At that, all good men shrieked at him, "Your idea is destructive of personal liberty and subversive of the power of the throne. To the Bastille with him." To the Bastille he went and languished there for three months, regretting he ever had had an idea.

Rousseau went to see him in prison, talked of the blind and suggested embossed letters that they might read. Nothing came of this. But good ideas die hard, or don't die at all but merely lie quiescent, waiting for the right man. So Valentin Haüy came across this one of Diderot's, picked it up, put it to work, printed his books with raised characters, taught his blind to read, to write, to play music. In 1786 he had gone so far that he could prove to Louis XVI that the blind could be useful and happy. Thanks to him and Diderot, blind people today are not forced to beg.

5

Ambroise Paré was a barber but he became for his time, 1510 to 1590, a great surgeon. It was he who first threw boiling oil and red hot irons out of the room where wounded soldiers were treated. In amputations he tied the arteries instead of burning them.

This was a big step by a big man. But one step was not far enough. Barbers clung to their crude instruments and continued to kill people. The doctors, who should have known better, weren't blameless in this matter. They looked down on surgery. The doctor had some sort of social standing—far above a barber—and it didn't make any difference what he called himself, a surgeon was a barber. Pride was of more importance than the relief of suffering.

The change in this attitude came slowly, following the work of wise and brave men. The pioneers in surgical progress were French. Pierre Dionis, who died in 1718, wrote treatises on anatomy and surgery that circled the globe and were translated into Chinese. Jean Louis Petit, 1674 to 1750, was the first to write of blood clots forming in wounded arteries and he was the first to perform an operation on the mastoid process. Dominique Anel, Pierre Brasdor, Pierre Joseph Desault and Nicholas André are the names of other Frenchmen who pushed surgery forward. In Germany about the same time were Lorenz Heister, August Gottlieb Richter and Johann Ulric Bilguer, one of the great Frederick's surgeon generals. England had William Cheselden, Charles White, Percival Pott and John Hunter.

This name, John Hunter, will live as long as surgery is necessary in this queer world. He was born in 1728 and was twenty years old when he reached London.

His older brother William was already an accomplished surgeon, but John wasn't interested in wounds or how to treat them. He wanted a good time. A seat in the gallery at a theater with the rest of the night spent drinking and yelling in a barroom was his idea of how life should be lived. Such conduct struck brother William as slightly foolish. So he dragged John to school, set him down in the dissecting room—and that was the end of the high revels.

For John developed a passion for anatomy and a year later was teaching the subject and studying surgery with Cheselden and Pott. A high spirited "northern god struck by lightning," he poured all of his restless energy into his work. He had a vile temper which he was at little pains to control, but he was naturally kind and readily sympathetic. His temper led to his death. He suffered from heart disease and when contradicted in a public discussion he flew into a rage—with results fatal to himself.

Hunter was a laboratory worker and the founder of experimental and surgical pathology. He described shock, gunshot wounds, inflammation and surgical diseases of the vascular system. He used artificial feeding by means of a flexible tube passed into the stomach and designed his own machine for forced respiration. He taught that abnormalities are the result of arrested development and that the embryo, in each stage of its existence, resembles the final form of some lower order. He wrote on the natural history of the human teeth, on venereal diseases, and a treatise on the blood, inflammation and gun-shot wounds. Under the influence of this man surgery became almost respectable. But it was, and continued to be until the time of Joseph Lister, one of the most hazardous of occupations—for the patient.

6

Surgery was advancing, but how about medicine? For the most part bland and blank ignorance. Doctors were learning more and more about human physiology but disease remained a baffling mystery. It was treated empirically, blood letting was the cure-all, and the causes of diseases were lost in absolute blackness.

Since no one knew, anyone might be right and the patent medicine quack came into his own. Enormous fortunes were piled up in this way, their foundations resting on the pains and aches of men and women. Among the most popular patent nostrums were Stoughton's Great Cordial Elixir, Betton's British Oils, John Hooper's Female Pills, Ching's Worm Lozenges and Della Lena's Powder of Mars. It was a cagey disease that could escape these cure-alls.

In addition to these major quackeries there were any number of other things that the hypochondriac could use in his search for health. There were, for instance, saffron drops, sugar plums, necklaces for pregnant women and teething babies, and Macassar oil to make the hair grow.

Elisha Perkins, a shrewd Connecticut Yankee, knew as much about human nature as Barnum ever did. He patented, in 1798, his magnetic tractor. This was a compass-like affair with one arm blunt and one sharp. Cures were made by stroking. England fell for it with a dull thud and Perkins transmuted ignorance into hard cash. Later an exposé killed it but by then Perkins was too rich to care.

Since the doctors of the time knew next to nothing, a consultation among them was simply a wrangling match, sometimes ending in a fist fight or worse. John Williams and Parker Bennet, both physicians of Ja-

maica, quarreled over a case of bilious fever. They got into a fight, were separated and instantly challenged each other to a duel. The next day, December 29, 1750, they met, armed with swords and pistols. It was no sham battle. Both men were killed. Confidence in one's opinion about bilious fever could hardly go farther than that.

This was the state of surgery and medicine at the beginning of the nineteenth century. Fifty per cent of those operated upon died. Death following child birth was so common that pregnant women were in constant terror of their ordeal. Yellow fever was a nightmare to New Orleans, Memphis, Philadelphia. Malaria was a scourge in the presence of which doctors were practically helpless. Every summer thousands of babies died of cholera infantum. There was no known cause for these diseases and there was no known cure. There were only dread and suffering while humanity muddled along hoping that by some miracle the birth rate would beat the death rate—and keep the nations plentifully supplied with cannon fodder.

7

It was into this kind of world that Louis Pasteur was born. There should be some sort of a celestial bell sounded in the Pleiades or chimed across Orion when a man like Pasteur opens his eyes and looks about him. But this baby kicks and cries and plays with its toes exactly like any other baby. It has chicken pox and measles and digs in the dirt and makes mud pies and gets spanked and cuddled and spoiled and treated as though it were just another baby.

Louis behaved like other boys as he played about the tannery on the banks of the Cuisance, at Arbois, where his father, Jean Joseph, tanned skins and made

a living for his small family. There is no record of a flash of genius revealing itself at a precocious age. He played in the pits, learned the smell, not pleasant, of green and drying hides and went to the school and was the smallest boy there and wanted to be a monitor and was rated as only average good.

Louis, sturdily at play, would see the important men of the town march grandly across the small bridge over the Cuisance, without so much as a glance at the boy or his hard-working father. Especially, there was General Baron Delort, aide-de-camp to Louis Philippe, who considered that he bestowed immortality upon Arbois by living there and translating Horace. But it was a little boy in ragged breeches, who held in his small and dirty fist immortality for Arbois and distinction for all France.

8

Louis's father was not educated, save in the business of being a soldier. He had fought for Napoleon in Spain and on the fields of France. He had been decorated with the Legion of Honor and made a sergeant-major. At Fontainebleau, April 5, 1814, he saw the emperor, who was then moving swiftly toward the end of his glory.

A hard-fighting, hard-working man, this Jean Joseph. And with a head on his shoulders, inside of which an idea or two spins around. One is that his son deserves an education, is entitled to something better in life than a heap of pits for tanning skins. This, of course, is what comes of revolution and the loss of social distinction.

Jeanne Etiennette Roqui, selected to mother this genius, had no more education than her husband. But she was vivacious, quick, laughing, and imaginative.

A spark of something divine had got into her soul. This spark she passed to Louis, and the son of tanners and lamp-makers turned out to be an artist, a scientist, a creator. There is a miracle for you, and where is your hard, logical explanation?

It was old Romanet, head of the college of Arbois, who put into the heads of Louis and of his father the idea of the great normal school at Paris. To make a teacher of Louis would be a big step up and something of which old Jean Joseph could be proud.

To Paris, then, went the boy, who would soon be sixteen. It would be hard to scrape up the money, but surely the investment was sound. But Louis was timid. Paris overwhelmed him. He could find no anchorage there. Memory of the tannery haunted him. "Oh, if I could but smell it again, I think I should be cured!" he cried. His work in school interested him but he could not forget the fine open country back there at Arbois. He ached with homesickness, and his hatred of Paris was burning him up. He had been here a month, yet it seemed to him years since he had looked in his father's face.

Luckily Jean Joseph understood, having learned, maybe, on those distant marches in Spain. He came to Paris, and he and Louis went back together to Arbois. Here was the bridge, here was the tannery, here was the little house. Home. The cure was instant and complete.

Louis went back to the college of Arbois, and contentment flowed around him. Even when it was no longer enough for him, he was silent about Paris and the normal school. Besançon was only thirty miles away. There he could do his preparatory work—and see his father several times a year.

After Besançon, again he went to Paris and the nor-

mal school. No talk of homesickness this time. That he had outgrown or lost in his earnest fight for knowledge. But poverty dogged him, and there was neither time nor money to waste raising hob in café or studio. His day started at six in the morning and ended late at night. So there was no carousal for this boy, no sly love-making, no cheap affectations. There was only work and a growing interest and a quick discovery that the finest thing in the world is science.

In this spirit he finished the normal school, experimented with crystals, won the friendship of the celebrated Jean Baptiste Biot, physicist, member of the Academy and prolific writer. Finally, at twenty-six, ready to take up his work as a teacher, he was made professor of physics at Dijon, where he remained a year, chafing and fretting, writing windy letters asking to be transferred, begging for a place at Besançon. Was he again homesick? He wanted that job because it was near Arbois. Yet he seemed momentarily quieted when he got an assistantship in chemistry at Strassburg.

9

M. Laurent, rector of the academy at Strassburg, had three daughters; one was married, one was not yet old enough to marry, one was just right, as Louis soon decided. Indeed he had been in Strassburg less than two weeks when he wrote to M. Laurent:

"An offer of the greatest importance to me and to your family is about to be made you on my behalf. . . . In short my father will tell you that I want to marry your second daughter, that I am twenty-six years old, or nearly, have made some reputation through my scientific labors and haven't a cent except what I earn."

To the young lady herself he wrote:

"My recollections tell me that those who have known me well, have loved me deeply"—but among them there had been no girl of Paris, you may be sure of that. To his chum he wrote, "Every quality I could wish for in a wife I find in her." Lucky man, then and always; for they were married and lived happily ever after.

This was Pasteur's romance, this was the love-making of a scientist. But not then and not afterwards did Madame Pasteur make any complaint. She knew the kind of man she had married, and she did not expect from him many of the things a smaller man would have given her. She took care of him, bore him children, fussed in a quiet way over her family—and was a calm, steady background for Louis's nervous activity and hot scientific quarrels.

She had in her mind no room for jealousy of Pasteur's work; she was willing to play second fiddle to the laboratory—and for all of her life that was exactly what she did. She sighed as the dinner got cold or she sat nodding waiting for Louis to stop work for the night, but she made no complaint. She was his wife, but science was his mistress; and she learned to sleep while an anxious, tired man peered at strange things through a microscope.

10

Lille's stolid citizens don nightcaps and start their snoring early. That is a habit they have from their ancestors who eight hundred years ago founded this country town. True, there is one window illuminated, and for a while that late light was a nervous strain on Lille. But as it held there night after night, even these hard-working shopkeepers came to ignore it or at least

condone it. Did not everyone know, by now, that the crazy Pasteur labored there at some devil's business of his own? He came to us from Strassburg and has been among us eighteen months and nothing has happened. Doubtless he is mad, but harmless.

Indeed, in this summer of 1857, the crazy Pasteur is at work in that little room, which is hot and stuffy, littered with bottles, test-tubes, retorts, gas-burners, a queer sort of oven for keeping things hot, abominable messes in glass jars, in basins, in anything that would hold them; and each smelling worse than the other. In the midst of this débris is a little bewhiskered man, to whose nose eye-glasses cling only by an act of God. His hands are filthy; his forehead, where he has rubbed a thoughtful finger, is smudged; his hair is on end; his clothes are a stained disgrace.

Is he really mad? Watch him, then, and decide for yourself whether his actions are those of a rational creature:

He takes a bottle out of his queer oven, looks at it, shakes it, peers at it again, mutters, stamps his foot, puts the bottle, not gently, back into the oven. Then he paces the room, looking at everything, seeing nothing. He takes a glass rod and stirs this mess and that, sniffing at it. He stands perfectly still, his hand held rigidly before him. Is he going into a trance? No; for suddenly he dashes the glass rod down and pounds the table with his fist. His face is inflamed with passion as he cries:

"There must be a way, there is a way to make these damned things grow."

Is all of this rational? To don nightcaps and hide in the feathers—that seems wiser, and safer.

These struggles, at midnight and alone, when he is

soiled, discouraged, exhausted, are for what purpose? To satisfy a curiosity, to prove a theory. Is the acid of sour milk the result of a chemical change, or is it caused by microscopic life? No one in all the world can answer that question for Pasteur. He must dive into these messes of yeast water and get an answer for himself. He dives, with his glass rod, time and again. The microscopic rodlike things to which he has pinned his faith are stubborn and set in their ways. It is slow work learning their likes and catering to their appetite.

He tries many things. Then he hits on yeast water, strained, sweetened with sugar, and enriched with carbonate of chalk. Into this he plunges some of the little rodlike things—and then he waits. His answer is now in the lap of Time. Again and again he returns to this bottle of yeast water. No change. Would a sane man lose his sleep and waste his strength watching a bottle of sweetened water in which nothing happens?

For the hundredth time he takes that bottle of yeast water out of the oven, holds it up to the light, squints at it. At last is there not something here? A grayness? With hands that tremble he wipes his glasses and looks again. There is something. Quick then with your glass rod and probe this something out.

Pasteur is quick. A drop of this grayness is on a bit of flat glass, another bit is on top of it. He slides the whole under his microscope. Then he stops. He is a brave man, but his nerve fails him. Dare he look? If the little rods are not there, shaking themselves in sign of strong life— He looks. A trembling in all his limbs seizes him. The rods are there—millions of them, giving every sign of life and strength. He has found his answer. These rods are alive, and it is they which change sugar into lactic acid. Without them that change can never take place.

## II

But what of it? Was it, in the first place the question of a sane man? Louis has worn himself out in an effort to prove that these things grow. But this change, sugar into lactic acid, has been taking place for thousands of years. What good does it do Pasteur to know that these little rodlike things do the work?

That's a hard one for him to answer just at this minute. He can, and does, tell the brewers that if they keep the rods out of their vats they'll always get alcohol and won't have any trouble with the stuff turning sour. But he doesn't, at once, tell them how to keep the rods out, and, anyway, something bigger is looming out of the shadows, taking vague form in his mind; it is a madness of course, and yet—

See how this man's mind works: It is proved that fermentation is caused by things that are alive. There are several different kinds of these ferments, and each kind does its own work. Now, among animals is there anything like this fermentation? He thinks there is. He thinks putrefaction is enough like it to be its first cousin.

But there is an idea even bigger and more important than that shaping itself in the head of this nervous Frenchman. What about disease? Hydrophobia, typhus, gangrene, yellow fever, cholera? Is it possible that each has a germ? At this point his imagination runs away with him. He peoples the air with germs, deadly enemies of human life, from which no one is safe. But these are dreams. He is miles ahead of himself.

How to prove these things? He sees, at present, no way. It is all dim, hazy, his path fog-hidden. But if he should break through, come out on some mountain-top

where the sun shines, stand there glorified, pointing humanity the way to health? That, also, may come if one is content to go carefully, one small step at a time, until the mists clear and the horizon widens.

12

These dim ghosts of thoughts excited Pasteur. They did not excite others—or excited them only to ridicule. Louis was no doctor, and the medical fellows turned their noses up at his theories. He was not sure of himself—how could he be?—but his genius had stirred, and the end toward which he was moving, blindly, was never again abandoned, was taken up more actively than ever after he went to Paris and joined the faculty of the normal school.

Louis's enemies laughed at him from behind the specter of "spontaneous generation." This life that is found in decaying meat has come into existence through some activity in the meat itself, they declared; these low forms have neither father nor mother—they are self-generated. If this isn't true, where under the sun do they come from? "Out of the air," answered Pasteur, and proceeded to prove it; did prove it, so that all the world now accepts his statement.

His enemies, however, refused to believe, and they went on fiercely multiplying experiments to show him up. Pasteur fought back—with harsh words and strong, beautiful experiments. But a calamity broke into the midst of this strife, which had grown bitter, and Louis was dragged away to save the silk industry.

The south of France, where the silkworm fed on the mulberry leaves, had known great prosperity; it now knew poverty and ruin. The silkworms refused to eat; they did not spin cocoons from which the beautiful silk could be unwound. Plantation after plantation lay

wasted, fallen into decay—the owner a bankrupt. They were destroyed by little brown specks, barely visible on the body of the precious worm. Experts were helpless; they said to do this, and they said to do that; and nothing worked.

What did Pasteur know of silkworms? Nothing. He was a great man with his ferments, but silkworms don't ferment—they die. This pebrine, this pepper disease, came from nothing, spread amazingly, scattering ruin out of its little brown spots. And could Pasteur change this? At any rate he could make things no worse, so then let him try.

Pasteur tried. He had infinite faith in his microscope, so he split up silkworms and looked at them through his glass. He found tiny specks in them—and he jumped to the conclusion that these specks were the cause of the disease. He showed the farmers how to use a microscope and told them if they kept the eggs from worms that had no specks inside them, they'd get a fine crop of silk. The farmers did as he said—and the next season the loss was greater than ever.

Pasteur had failed. Like a madman he rushed back into the strife. He found that the tiny specks he had noticed were alive, that they multiplied swiftly, bringing death to the worm. There at last he had the whole secret. He would now tell the farmers how to grind up the whole body of the worm and search it, under the microscope, for the specks. If the worm was healthy, the eggs would be healthy. This time he was right. He had saved the silk industry—and there was talk of erecting a gold statue to his memory.

13

Yes, he saved the silkworms, but he ruined his health, and he narrowly missed an early grave. He had worked

over those worms, like a demon, giving to the problem his last flutter of nervous energy. He had won through to a clear answer when paralysis struck him. This human machine cannot go on indefinitely, driven only by an act of will. Since the opening of the war to save silkworms, Pasteur had slaved relentlessly, and he had endured two severe emotional shocks: His father and his daughter had died. Yes, old Jean Joseph, whom Louis loved, had fallen asleep at Arbois. At his side was lying Cécile, the second of Pasteur's daughters to die. This strange Pasteur, who seemed to love only the bugs under his microscope, was a devoted son and father. A showman, a man of large gestures, he yet hid within him a deep fund of sincerity and a passionate devotion to family and friends.

When the crash came, it was complete. France heard that her great man was dying. This cerebral hemorrhage was severe, and the whole left side was dead. The doctors who rushed to attend him were in despair. One does not recover from such an attack, but Pasteur recovered. His work was not yet done. His will drove him from bed, forced him back to the laboratory, led him to other and more startling discoveries. The man was an enigma. It was as though he defied Fate to kill him before he disclosed the secrets of disease.

14

Pasteur had saved the silk-growers of France; he had also done something for himself; he had proved that at least one disease, this of the silkworms, was caused by a germ. It is true that over in Germany Robert Koch had discovered the anthrax bacillus; but Pasteur would accept no evidence except his own, and he was primed to go after any disease that threatened.

Naturally Pasteur was thinking of men and women,

but the farmers of France wouldn't let him alone. Their sheep were dying off, the loss each year totaling twenty million francs. "Save our sheep. Do this for France," the farmers cried, and Louis, touched in a weak spot, undertook to do it. It was hard work and accident played some part, but he did it. He took a culture of anthrax and weakened it, attenuating it to a point where a shot of it would make a sheep a little sick and less frisky for a day or two. But afterwards this inoculated sheep was unaffected by all the anthrax bacilli in the world.

The sheep doctors laughed at Pasteur and his inoculation stuff. Not liking to be laughed at, when he was challenged to give a public demonstration of his treatment, he accepted. He may have trembled as he thought of the hundred and one things that might happen to make a monkey out of him, but he didn't hesitate. If his vaccine worked, and it did, with a dozen sheep in his laboratory, it would work with a hundred or a hundred thousand outside of the laboratory. So bring on your sheep, you skeptics, and we'll see who has the last laugh.

Forty-eight sheep, two goats, and some cows were offered up as sacrifices to the god of science. Pouilly-le-Fort, a farm near Melun, was chosen as the site of this strangest demonstration in the history of medicine. Strangest, but not the most dramatic; the most dramatic was yet in the future, to be staged by this same little paralytic in his laboratory at Paris.

The sheep, innocent and healthy, were waiting for Pasteur, and his assistants at the farm on May 5, 1881. In addition, two-legged sheep had come from far and near, some of them hopeful, some doubtful, all ready to turn on little Pasteur if things went wrong. Rossignol, one of the editors of the Veterinary Press, was

there. It was he who started all this business—and he hadn't the slightest confidence in Louis and his vaccines. He was a big man, who winked at his friends and made his eyebrows say: "See what a clever man I am! I've got this Pasteur out in the open, at last, just for the purpose of showing him up." Newspaper men were present, because this thing that Pasteur said he could do was sensational, of interest to every sheep-raiser, and success or failure, it would make red-hot news.

Half of the sheep were inoculated with the weakened virus; the others, those condemned to death if Pasteur were right, were left alone. Their turn would come later. On May 17 the inoculated sheep got another shot of anthrax bacilli, stronger this time. More days passed, with nothing to do but wait and be patient. On May 31, death-dealing charges were shot into all the sheep, the goats, and the cattle. If Pasteur was right, the inoculated sheep would live and the others would all die. June 2 came, and proved Pasteur right. Everyone of the sheep he had made immune was alive and well; twenty-two of the others were dead when Pasteur arrived at the farm at two in the afternoon, and the remaining two were dying. He had been one hundred per cent successful.

Rossignol, the big man who had laid the trap to expose Pasteur, was one of the first to congratulate him. The story of the experiment circled the globe. Ask your grandfathers; they can tell you of the thrill they got when the report appeared in their farm journals. Pasteur was the great magician. Three times he had waved his wand, and at each movement a stream of gold had poured forth; once for the wine-makers, once for the silk-workers, and once for the farmers. No wonder he was popular; he had entered the heart of France through its pocketbook.

15

But this cripple, this limping, gray-haired man of sixty, was not through. He had taught France to heat its wine—pasteurize it—and so save it from turning sour; he had taught the silk-growers how to beat the pepper disease and have healthy weavers; he had taught the sheep-men how to save twenty-million francs a year, and in pure science he had killed the idea of spontaneous generation.

More than that, he had been an inspiration to Joseph Lister at his hospital in Edinburgh. Out of Pasteur's work Lister drew the idea for antiseptic surgery, and with the use of carbolic acid and the cleansing of instruments and bandages, he had greatly reduced the frightful mortality of operations and child birth. He wrote Pasteur:

"In our hospital you will see in a large measure how humanity has profited from your work."

Yes, and is still profiting, though antiseptic surgery has passed, now, into aseptic surgery. But no matter what changes are made in the operating room, the line leads straight back to Pasteur and Lister and Robert Lawson Tait. If today you can submit to a major operation, confident that the chances are all in your favor, it is because Pasteur found invisible enemies in the air, and because Lister and Tait found a way to beat these foes.

Sixty years old and so much done! Time to rest? You don't know this man. Even while he was torn with anxiety over the sheep experiment, he was working with mad dogs. No one knows why he chose to work at hydrophobia. There was no epidemic of the disease; comparatively few people in a century got it; but those who did died—horribly. Why ask

what started him? What we should do is thank God he did start.

Imagine the wild times in Pasteur's laboratory during this period. Mad dogs howling through the night, mad guinea-pigs, mad rabbits, a mad Pasteur, driven distracted through failure; mad assistants, goaded to desperation by a master who never quits; red-eyed, insane, searching for a germ that won't reveal itself. Madame Pasteur, no longer young, lives quietly in the midst of this turmoil, does what she can to soothe the nerves of a man who is all nerves, and for whom there is no soothing this side of the grave.

And the bug he seeks won't reveal itself, and no cure reveals itself. The dogs die, and the rabbits die, and their diseased spinal cords are removed, ground up to make more virus to infect more dogs. An endless chain. What comes of it? Only distraction to a limping master and a sort of sleepless horror to his young assistants. These young assistants are ready to quit; they are ready to say, and do say: "This thing cannot be done. The bug escapes us, and we know little more now than we did when the first mad dog came into our laboratory."

Pasteur will not quit. His is the blind genius of the man who doesn't know when he is beaten. His young assistants are going blind at their microscopes, but Pasteur savagely keeps them at work, doing over and over the same experiment. Himself he drives hardest of all. This mad-dog business is never out of his head. He devises weird experiments that fail. His imagination pictures things that cannot be done; his assistants do them. Truly, this laboratory is a mad house, and one expects, at any minute, to see froth upon the lips of Pasteur!

No germ is discoverable, and that search they defi-

nitely give up. But cannot this fatal virus be tamed? Turned from a murderer into a friend? If it can be done, Pasteur and his young men will do it. They try everything. Olympian gods gone crazy could suggest no more amazing experiments. It is almost wholly a trial-and-error system. And everything fails. But wait. One inoculated dog recovers and is forever after immune. What happened? They search back, trying to discover what had weakened that virus. They repeat their experiments. This one ray of light, this one immune dog, fires them, is a strong stimulant. Now they cannot fail—nor do they.

From a rabbit dead with rabies they remove the spinal cord and hang it up in a germ-proof bottle to dry. For fourteen days it hangs there shriveling and shrinking. After fourteen days they grind up what is left of it, they mix it with water and make a virus which they inject directly into the brains of well dogs. The next day they use a stronger virus, made from cord that has dried for thirteen days; and so on for fourteen injections. On the last day the dogs get poisonous shots sure to kill.

But these dogs did not die. They were immune. Pasteur and his young men have come out of the mad house into the light of a great sun—and it is morning in their souls.

The experiment must be repeated. It is repeated a hundred times. It is proved that dogs can be made immune to rabies. And if there are no mad dogs, there will be no human beings dying of hydrophobia. But it is not possible to vaccinate all of the dogs in France. The great discovery seems useless. But does it not point to something?

Pasteur's imagination is again fired. He rushes to his laboratory and prepares for his great test. Into

the brain of a healthy dog, one that is not immune, an injection of deadly virus is shot. That dog will develop rabies and die. No power on earth can save him unless—

Let us give this dog an injection of the virus fourteen days old, and follow that day after day with injections of stronger and stronger virus. It is done, and the dog, doomed to death, does not develop rabies, does not die. He is cured. As far as dogs are concerned, this frightful disease is conquered.

How about people? Pasteur broods over that question, while he goes on trying out his treatment on dogs. Each dog recovers; there is no failure. His confidence mounts; he announces a cure for hydrophobia. If his weak-to-strong virus saves dogs, it will save men. He is sure of it; so sure that he is willing to have himself infected with the terrible disease.

16

However, his scientific urge is not put to that test. Fate steps into the drama. Nine-year-old Joseph Meister has been bitten in fourteen places by a mad dog. That was two days ago at his home at Meissengott in Alsace. The boy is certain to die—unless Pasteur can save him.

Pasteur, who was so sure he is right that he has talked of giving himself the disease to demonstrate his cure, trembles in the presence of this mother and her whimpering child. He is suddenly too tired to think; he can decide nothing. He has made himself into a god, and his divine responsibilities crush him. His cure has worked on dogs; will it work with this boy? Will his fourteen injections make him a savior—or a murderer?

He finds a room for the woman and her boy; he tells

them they must wait; he will see them at five o'clock. Why does he hesitate, he who was so certain when he spoke to the Academy? Ah, then he was dealing with a theory that he thought had been proved; now he is faced with a fact, the proving of which may destroy him.

In this state of sweating doubt and fear he hurries to his doctor friends, Grancher and Vulpian. These two have seen his work on dogs in the laboratory; they believe in him. They go with him that evening to see the bitten boy. They study the red festering wounds. Here is no room for doubt. They tell Pasteur:

"The boy will almost certainly die unless you treat him. Go ahead with the injections."

The first dose of weakened fourteen-day old virus is shot into the boy's system. Pasteur's confidence returns. He writes his son: "All is going well. The child sleeps well, and the inoculated matter is absorbed into the system from one day to another without leaving a trace." But this calm assurance on his part cannot continue. The injections are growing more and more deadly.

"Your father had another bad night; he is dreading the last inoculations on the child. And yet there can be no drawing back now," writes Madame Pasteur to her son.

Joseph keeps well. He and Pasteur have become great friends, and the boy runs to the graying man each night for a kiss before he piles into bed. This warm affection does not make Pasteur's work easier. Is he murdering a child that loves him? God knows. But there "is no drawing back now."

On the twelfth day virus, powerful enough to kill, is injected. The boy kisses Pasteur and goes to bed and to sleep. Not so Pasteur. He retires late and spends

the night tossing on his bed. But in the morning the boy is bright and happy. There are more days of waiting. Hydrophobia develops slowly. In this boy it never develops. Pasteur has succeeded.

Victims of hydrophobia need not die. This Frenchman at Paris will save them. They come to be saved. A boy, fourteen, who has saved his small companions at the risk of his life, is the second patient. He is cured. Four little ones come to him from America, their expenses paid by a public subscription raised by the New York Herald. They are saved.

One child is lost. Louise Pelletier, ten, had been bitten on the head by a mad mountain dog, and the wound was thirty-seven days old. At any minute now hydrophobia can be expected to manifest itself. Here again Pasteur faces a crisis, and again he proves the stuff of which he is made. If he fails with Louise the skeptics will say: "You see? Pasteur is only guessing. His cure turns out to be no cure. As for me, if I'm bitten I'll take my chances and not run off to a man who isn't even a doctor." Pasteur could hear them saying just that as he sat and looked at Louise, and doubted in his own mind the wisdom of giving her the cure.

But the humanity in him won. He gave the injections. For a little while hope stirred. Louise returned to school, but soon there were attacks of breathlessness and spasms. At the appearance of these alarming symptoms, Pasteur rushes to Louise, gives more inoculations. All day he sits at the girl's side. She fumbles weakly for his hand, clings to it as the last friendly thing on earth. When it is all over, when Louise has quieted into the sleep of death, Pasteur bursts into tears. His arms are around the weeping father and mother. "I did so wish I could have saved your little one," he told them.

When you think of Pasteur, the showman, remember Louise Pelletier. This man, whose conceit bristled all over him, who could not endure opposition, whose scientific debates descended to wrangles and personal abuse so cutting that an opponent would challenge him to a duel, this unsystematic discoverer who loved the limelight and fattened on praise, is after all, beyond our criticism. He is too human for us to censure; he is too powerful and too many-sided to be understood.

17

There enter Paris, early in March, nineteen fur-capped men. They are bandaged, and five of them are so ill they cannot walk. It is a ghastly little procession. They are Russian peasants from Smolensk—and each of them has been badly bitten by a mad wolf. For ten days the poison of madness has been working in them. This poison moves slowly, but in ten days it must have gone deep, moving inevitably toward spinal cord and brain.

They have come all this long distance, these peasants, hopefully, like children, laying their lives at the feet of this master magician. Can Pasteur save them? He can try; and there is no hesitancy this time. He starts with two injections each day, in an effort to make up for lost time. The five who cannot walk receive the treatment at the Hôtel Dieu Hospital; the other fourteen come to Pasteur's laboratory. They know enough French to get about since they know the one word, "Pasteur." At mention of that name any Frenchmen will show them the way.

Three of the fated Russians die; sixteen are cured, can go home safe and confident. But in a world of petty imperfection and jealousy, the great man must be one hundred per cent right.

In Russia, however, there is no criticism. On the contrary there is wild rejoicing at the return of the sixteen. These survivors are held in awe, as if they were men risen from the grave. They had been sent to Paris to die; they return alive and well. To the mujik it is simply a miracle.

To the czar himself it was little short of that and he sent the Grand Duke Vladimir to Pasteur with the diamond cross of the Order of St. Anne of Russia, and a gift of one hundred thousand francs to be used in building the Pasteur Institute.

Nothing the czar could have done would have fired the French heart so instantly as his mention of the Pasteur Institute. All France wanted that. Lists were opened, and men and women fought with each other in their eagerness to show their love for Pasteur. Millionaires and scrubwomen joined in raising this fund. And what name is this on the list from Alsace? Joseph Meister of Missengott! Thus was this temple of health made possible by the free offerings of an adoring people.

18

Properly the story of Pasteur's life ends with the defeat of hydrophobia. Into this last fight he put all of his strength, and now he has no reserve upon which to draw. His friends persuade him to take a vacation, and he goes away, still full of fine plans for the future. But the rest fails to rekindle the old fires. Returning to Paris, he is present at the opening of the Pasteur Institute, and is so overcome with emotion at all the fine things said about him that his son has to read his address.

He lingers on at Paris, watching the young men who are taking up his work, especially interested in

the efforts to rob diphtheria of its sting. He is ill again, but recovers, or seems to recover, and goes limping about, his bright eyes seeing everything.

A great fête was planned in celebration of his seventieth birthday anniversary. Fate reserves this, the most dramatic moment of his life, for the closing scene of a career that, for fifty years, has seethed with drama.

The date is December 27, 1892. The great hall of the Sorbonne is packed. Delegates from foreign countries and from the French societies of science occupy the seats of honor. Duclaux, Roux, Chamberland, Metchnikoff, those four who have worked with Pasteur, are present. One is absent, Thuillier, who died at Alexandria, a victim of the cholera which he went out to study. A little of the glory of this great day falls upon his young shoulders!

Notables enough are present: ministers and ambassadors, senators and members of the Chamber. Everyone is in his finest array of clothes, everyone is distinguished for this or that. But out of this crowd of dignitaries is one whose face compels attention. His hair is long and waves over ears and collar; side whiskers frame clean-shaven lip and chin, and the mouth is a little twisted. The face is lined, for this man is no longer young and he has worked hard. He has looked upon the souls of men and women when pain has torn away the barriers, and this shows in his eyes, which are troubled and sadly thoughtful. This man is English and his name is Joseph Lister—a name likely to last as long as the English language itself.

A little old limping gray man, clinging to the arm of the President of the Republic, enters the hall. Instantly the band of the Republican Guard strikes into a triumphal march. Everyone rises, everyone cheers. The great moment has come. There are addresses,

eulogies. The greatness of this Pasteur is told in a dozen different ways. They all amount to this: "Who can say how much human life owes you, and how much more it will owe to you in the future?"

Pasteur listens to these fine words, not now with any sign of cockiness. This man, who in an argument would browbeat angels and out-shout divinity, has always been, in the presence of a sublime event, singularly humble. He is humble now; he is choked with his emotions. Lister rises. "You have," he told Pasteur, "raised the veil that for centuries covered infectious diseases" —pointing to the debt humanity owes this Frenchman.

At the conclusion of the address Pasteur rises and embraces Lister. The spectators weep and cheer.

Pasteur's voice, with which he has roared down so many opponents in the past, is now but a thin squeak. Again he cannot give his address, and his son must read it for him. This man has been called conceited and domineering. There is none of that spirit in these words from his address:

"Whether or not our efforts are favored by life, let us be able to say, when we come near the great goal, I have done what I could."

19

On June 13, 1895, Louis Pasteur went to Villeneuve l'Étang, where, it was hoped, he would recover his health.

During the summer months he read, he talked with Roux about his work on diphtheria. He expressed confidence in his recovery. But all the time he grew weaker, the paralysis increasing, speech becoming daily more difficult.

No longer could any member of that devoted little band at Villeneuve l'Étang entertain hope. Pasteur's

days were numbered. On September 27 his last agony began. The pain was frightful, while the paralysis crept on, killing more and more of this active body. Madame Pasteur at his side held one of his hands; in the other this devout Catholic held a crucifix.

That is the last picture we have of Pasteur. In a few hours he was dead. But this man you will not be able to forget. As you drink your pasteurized milk, as you go fearlessly into a hospital, as you realize that your child need not die of diphtheria poisoning, as you feel that you are protected against enemies that destroyed your great-grandparents, you will remember Pasteur, his work, his strange, contradictory human life, and the fine health-giving principles that sprang from his genius.

## *Chapter Twenty-four*

# CHARLES DARWIN

CHARLES DARWIN sat in his study, and Fear squatted at his side. From the garden beyond his window came the subdued voices of his children. It was June in the quiet village of Downe, but there was no June in the hearts of the fathers and mothers.

Scarlet fever was striking, swiftly, blindly, and no child was safe. Charles Darwin knew well the meaning of that terrible disease, for seven years ago it had stalked through his home and borne away in its flaming arms Anne Elizabeth, aged ten, "the joy of the household." Even now as he thought of this "dear and good child" tears dimmed his eyes, because he does still "and shall forever love her dear, joyous face."

In the garden his children were again frightened and anxious, while in a distant room an eighteen-months-old boy was fighting for life. The baby was the youngest of Darwin's children—and he was "defective." Mother love had wound itself tenderly around that poor little helpless boy. If he could be saved, she would save him.

Charles had taken every precaution to protect his other children—those seven bright-eyed boys and girls, likely to grow up and make names for themselves in the world. They were the cause of his anxiety; he must keep these children well.

At such a moment work was impossible. He was in his study, but he was idle. He had not come here to

work; he had come to be alone and to brood. The world beyond his window was alive with the song of bird and the whisper of wind and the small murmur of growing things; intensely alive to this man, whose eyes, deep-set under overhanging brows, had seen farther into the heart of Nature and watched more curious things there than the eyes of any other man who ever lived. Each burnished feather, each blade of grass, each stone on the hillside had a message and a meaning for him. For almost thirty years, he had studied the moods of Nature. He knew her tantrums, her loves, her brutality, her tenderness, her prodigality, her selfishness, and her carnage.

He knew hidden and intimate things about her, and some of her questions he had answered and one of them, the biggest of all, he was soon to answer. For twenty years he had been gathering his forces for this answer. He had circled the globe, he had penetrated strange places, he had frozen in the Straits of Terra del Fuega and baked on the plains of Brazil; he had sought his answer in the high regions of the Andes and on the islands of the Galapagos; he had endured sickness and exhaustion and loneliness, to learn the words of her language; he had nauseated himself with ten thousand barnacles, until he hated them with a deadly hatred, that he might formulate his answer.

Twenty years. The need for the answer had come to him before he was married to Emma Wedgewood—and his oldest son was now nineteen.

2

Even with scarlet fever in the house, Charles Darwin, on this June day, 1858, could not entirely rid his mind of his work. It were better, perhaps, to remember it, and for a moment forget the worry that tore him.

His work was aimed to answer this question: What force made possible the different kinds of animals and plants? Special creation? He could not swallow that, though thirty years ago he had gulped it readily enough. Those were the days when he was preparing to be a minister in the Church of England. Paley's reasons then seemed adequate. Life, from that standpoint, was simple, and no questions worth twenty years of work presented themselves.

Charles Darwin could not cling to that simple faith. Nature broke his grip. In his five years of going up and down the world he had seen many things that were outside the province of a personal God. A God there might be, an impersonal, magnificent God; but every flower and every wee animal cried out against the God of the Hebrew scriptures, the God of England, the God of the nineteenth century. So Charles put that God away, and he put away also his own remote and splendid God as something passing the understanding of man—and gave his attention to barnacles and beetles.

But he did not put away kindness and charity. The children that gathered around his knee adored him, and his friends were devoted. He attacked no creed, he criticized no man's faith. "Let each man hope and believe what he can," said Charles, but for himself he put his hope and his belief in the largesse of Nature.

If not by special creation, how then had the species come into being? A glimmer of a vague answer had come to him back there in Galapagos days. There the species shaded toward each other, and the animals on Galapagos shaded toward those on the mainland of South America. Did an act of special creation put these live things on Galapagos and yet make them only slightly different from their neighbors? That seemed a useless subtlety on the part of God.

Or could he find a hint, a shadow of a hint, in this: No two things are exactly alike; differences creep in; of these variations some help and some hurt, some make life easier, and some make it harder. If easier, the plant or animal has a better chance to live and breed; if harder, there is less chance to pass along the bad feature as there is less chance of the plant or animal becoming a parent.

This was the small ray of light that came to Charles Darwin as he sailed in the Beagle, westward from Galapagos.

But how prove it? How convince himself and the rest of the world that he was right? Through more than twenty years of ill health Charles Darwin had been gathering data to insure that conviction. His square jaw and beetling brow were those of a man who never quits. "It's dogged does it," he said often, and dogged he was.

3

"Facts, facts. I must have proof," cried Darwin, as he began his colossal task of putting all nature through the sieve of his experiments and analysis. The theory was plain enough; that he had written out, briefly, sixteen years ago and more elaborately two years later. It was for proof that he had been working.

To a few people he had unfolded his theory. To the great geologist, Charles Lyell; to the naturalist, Joseph Hooker; to his doctor brother, Erasmus; to America's great botanist, Asa Gray; to a few chosen spirits, each of whom had looked upon his idea doubtfully. Yes, Charles Darwin knew that all of the world was against him. At times he himself doubted, and his faith grew cold. "For all I know," he thought, "I may be one of these monomaniacs. How can I be sure

that I am not letting my ideas and my hope blind me to facts that are right under my nose?"

But while his friends doubted and held back, they were jealous for his good name and admired the great work he was doing. "Publish your theory," they told him, "and publish it at once. Someone else may get the same idea, rush into print and so destroy your twenty years of work."

Charles refused to be disturbed or hurried by such words. Over and over he told himself he would not worry about being beaten by some other scientist. He was in search of the truth, he was free of jealousy, and he felt the credit could be left to take care of itself.

He was not without ambition; but it is easy to believe that his friends, his home, his children and his researches satisfied that ambition. If he were ambitious in a small way, why had he thrown away his chances? There were the two years at Edinburgh when he thought he was going to be a doctor—and had learned to hate the words "materia medica." There were the years at Cambridge when he thought he was going to be a minister—and had belonged to a dinner club and learned what it meant to drink too much. Lectures did not appeal to him; he'd far rather shoulder his gun and go off on a hunting trip. He had no serious, dominant interest. Bugs and rocks and flowers he studied, but only as the amateur studies them. It did not occur to him that his life's work lay in that direction.

4

But all of that was nearly thirty years behind this bald, graying man who sat shuddering at the possible fate of his children. What was species or a theory of

life when death threatened his dear ones? He rose to go into the hall to get a pinch of snuff. He was a tall man, slightly bowed, and the only lines on his face had been etched there by laughter and kindness and thought. He was forty-nine years old, and for eighteen years he had not known a well day. Yet his step was firm, his color high, his physique robust.

As he stood in the hall he heard far away the querulous moaning of the sick child—that poor defective for whom he could do nothing now and for whom he would never be able to do anything. If death were to end that broken life . . .

He descended the stairs and entered the living-room, where the day's mail awaited him. Idly he fingered the letters. Life's routine, he thought, moves ahead ruthlessly as though there were no such thing as sickness and death. Emma was with the sick child, and she could not, as was her custom, open his mail this morning and read it to him. The letters could wait; doubtless there was nothing urgent. . . . A flash of interest came into his eyes. Here was an envelope with strange postmarks and soiled from much handling. Charles knew that writing and eagerly he broke the seal.

"What has Wallace to say for himself now?" he mused. "Ah, he's been sick. No wonder. The climate of those beastly islands. But thank God, he's better. While sick he had some curious thoughts, eh? He wants my opinion. Thoughts about what? *The origin of the species and the part played by natural selection?* What? What!"

He sat in his high-backed chair and read slowly and painfully the long letter written to him by Alfred Russell Wallace, to the last words: "If you think this sufficiently important to show to Sir Charles Lyell, who has thought well of my former papers—"

Darwin sat still, and the hand that held the fateful letter did not tremble. There was no change in the expression of his face. But the deep-set eyes were overcast as though a shadow had come between him and the sun. He made no outcry; he did not even call Emma, but he sat alone in that Gethsemane of a room and absorbed his undeserved punishment.

Around him lay the broken shards of his life's dream, his life's work. Wallace, from the far-away island of Tornate, had destroyed him, for Wallace had written out, in clear bold hand, the exact theory upon which Darwin had been working for many hard years. There it all was, as complete as though it were an abstract of the paper Charles had written in 1842.

In the hard moments that followed the reading of that letter, Charles Darwin searched his heart, and he found there no hatred of Wallace, no jealousy of the man who had beaten him in the race. Not for an instant was he tempted to snatch from Wallace the honor that was rightfully his. But he thought of the ten thousand barnacles, of the twenty years, of the mass of notes accumulated and now useless. At the end he asked himself, "In what way can I best serve Wallace?"

5

On the sand walk that afternoon Charles Darwin went slowly. The vigor and joy had gone out of life. In the house behind him were sickness and depression and the creeping shadow of death. At his heels a little white fox terrier trotted, subdued and quiet, for he knew the master was in a strange state of mind. Not today did this tall man stand long gazing into the heart of a flower, or flip over stones with his stick in search of ugly bugs; not today did he pause for a

friendly talk with the old gardener. Today his eyes were blind to the world, for his thoughts were in a turmoil.

Had he, then, known himself so slightly? Had all his work, really, been for fame? Was he too small to court truth whole-heartedly and unafraid? Had he deceived himself and all his friends with a sham humility? Was he crushed because his spirit was not big enough to rise above petty personal questions? Was it true that in the deepest part of his nature he sought honor and distinction rather than understanding and wisdom? Where now was the joy he had once had in the conviction that he had honestly done his best?

He was already famous. And he was a rich man. In what way could the general acceptance of his theory add to his joy? If he wanted men to know the truth, could they not know it as well from Wallace? This obscure and unknown naturalist seeking truth in the far ends of the earth—was he not entitled to whatever honor his paper could win?

He already had sent the Wallace letter to Lyell, and he had written Hooker of the amazing bombshell that had wrecked his hopes. Those two would decide what was best to be done. For himself he had determined that Wallace's paper must be published at once, so that no question of priority could ever be raised.

But Lyell and Hooker would not permit him thus to sacrifice himself—to throw away the work of those twenty years. Here, they agreed, was the way things must be done: "This paper by Wallace and the paper, or part of it, that you wrote in 1844, together with some of the letter you wrote Asa Gray last year, will be read as a joint paper before the Linnean Society; and, afterwards, with these two papers on record, you

can go on with your work and publish your book without any infringement of Wallace's rights."

6

Thus Hooker and Lyell planned to save their friend and deal honorably with Wallace. But would their friend be saved? That for a time, as the slow days dragged, seemed doubtful, for Darwin, with a high sense of honor, clung to his belief that Wallace was entitled to all the credit. Hooker could argue and bluster, and Lyell could be smoothly persuasive, but Charles was not easily induced to change his mind.

In those dark moments, while fever was burning out the life of his son, he felt his own judgment was not to be trusted.

"It seems hard," he told Lyell, "that I should be compelled to lose my priority of many years standing, but I cannot feel at all sure that this alters the justice of the case."

Death came to little Charles Waring Darwin ten days after the arrival of Wallace's fateful letter. The passing of that crippled soul could not be counted a great loss by Darwin, who had looked with dread upon the years that stretched before his unfortunate son. But fear and worry and lost work and crushed ambition and death and a weeping mother, joining hands thus suddenly, bore him down; and sickness, ever at his side, had its way with him.

He lay on his sofa in his study and fought the nausea and headache that racked him; and through his pain the problem that must be solved at once cried for an answer. How could he agree to let Hooker and Lyell have their way? "First impressions are generally right, and I at first thought it would be dishonorable in me now to publish," he told Lyell.

"I cannot think now on this subject," he wrote Hooker. "I am prostrated and can do nothing. I dare say all is too late. It is miserable of me to care at all about priority."

"You have put your case in the hands of Lyell and me," Hooker told him bluntly. "You are our client and you must do as we say. You can trust us to protect both you and Wallace."

In the end Darwin could only say, "I will do anything. God bless you, my dear kind friend."

7

Charles Darwin sat in his study, and outside his open window June again sported itself. For a year the flowers and grasses had been growing above the grave of little Charles Waring; for a year a small group of scientists had been waiting for Darwin's proofs of his theory, and for a year Darwin had been working with all of his strength at the task of assembling those proofs.

The book was nearing the end. Murray would publish it on "handsome terms," though he had not seen the manuscript. Darwin had given his word that it was not "more unorthodox than the subject makes inevitable." That satisfied Murray, but would it satisfy anyone else? Lyell? Hooker? Gray? His old teacher in geology, Sedgwick? His Cambridge professor, Henslow? The great physiologist, Owen? And would it satisfy Emma Darwin?

Emma went cheerfully about her business of wife and mother. Seven healthy boys and girls are a handful for any woman, and Emma was not one to shirk her duties. Cheerfully, yes; but back of her smile was a half-formed shade of doubt, a mere touch of irritation at the thought that she could not understand what was

going on in the head of her husband. Often as he lay on the sofa, having fallen asleep under the spell of her reading voice, she would put her book down and study the face she knew so well—and would never know.

What was this thing that rose, impalpable as the thinnest mist, between her and Charles? An idea, a belief, an urge that was outside of and beyond any realm into which she could force her mind. Was this man whom she had married twenty years ago and for whom she had mothered ten children, a stranger? Was his world not her world, and his ways not her ways? There were whispers and lifted eyebrows and strange looks from her neighbors. Oh, she knew all about Charles' theory, had known for a long time, but had thought it not worth while paying much attention to it.

Now Hooker and Lyell were talking, and there were hints, which she could not miss, that the world—the nice, religious people whom she liked and looked up to—probably would laugh at Charles' idea and hate Charles. It came to her as a shock. Always kind, always patient, never complaining, thoughtful even in his sickness, how could he be hated, unless there were something hateful in his nature?

Such a trait could not be hidden from love, and she had loved him longer than these twenty years of married life. All of those five earlier years when he was sailing around the world, poking into queer places and never once thinking of her, she had loved him. And before that. She could not remember a time when she hadn't loved this fine, ready, brave cousin of hers.

Poor blind Charles! He had seen nothing of the love that she knew was in his heart for her, of the love that was beating fiercely in her for him. She had turned

away from the gay and handsome men who had courted her, though she had been tempted to marry some one of them during the five frightful years when never a word came to her from Charles. As hope faded and faded, she had been tempted, only to find that no other man could win his way to her heart. Hope died, but her love was brave and strong enough to last through those five empty years.

Men called her beautiful—and she was glad of that. They praised her bright eyes, her dancing curls, her keen mind. Surely, if other men found her fascinating, Charles when he returned, would not go to that little Fanny Owen, who flattered him and hadn't a brain in her head. Then Charles came home, and the warmth of Emma's love flowed around him. The wonder of it had opened his eyes, and the radiant miracle of it still glowed around her.

Now there had risen this intangible shadow, the source of which was this terrible book that Charles was killing himself to finish. Was it destructive of the things that had become part of her religious life? She hardly dared ask herself, "Will his book be, as they hint, anti-God?"

Emma's faith, that had been serene and confident, pondered that question. If Charles doubted, if these long years of work banished the God of the Bible, then—then God may have made a mistake, but Charles was right.

## 8

That summer of 1859 raced by, while Charles, in spite of sickness, worked fiercely to finish his book for fall publication. He could heave a great sigh of relief when the actual writing was done, but there followed the nightmare of reading the proof sheets. Those

proofs were in a mess when they went back to Murray. For Charles worried constantly lest some phrase might be thought obscure or some shade of meaning be missed by his readers. He was trying to let the light of clear reason shine into dark places, and he could never get enough light to satisfy him.

Anxious days followed the return of the final proof. Now the book was beyond his control; henceforth it would have to look out for itself. But Charles could not rest content with what had been done, and wrote endless letters in an effort to induce his friends to accept his theory. There were three who, before all others, he wanted as disciples: Lyell and Hooker and Huxley. Among Americans, he clung desperately to Asa Gray, eager to win the botanist to his side. Hooker and Huxley, ripe and energetic geniuses, were ready to go the whole way for their friend. Lyell hesitated, blowing hot and cold, waiting as it were for inspiration to shine around him.

Darwin wrote and hoped and shivered with apprehension, and felt that if he could win Hooker and Lyell and Huxley "all the rest of the world could rail but ultimately his theory would prevail." At times he was sure his book was right and true, and he dared to dream that men would accept and praise it. At another moment his faith would turn to ice, and his backbone would creep as he saw himself ridiculed and despised and hated.

But these thoughts were childish and he put them away from him; whatever the result it was too late now to turn back. November 24 was set as the publication date, and the binding of copies was under way. "If it is too late to retreat," thought Darwin, "then boldness is the best strategy." On November 11 he ordered advance copies sent to the leading men of

science in England and to Agassiz and Gray in America.

Of course there was a copy for his beloved Henslow, his "dear old master in natural history." If Henslow would take the trouble to "point out what parts seem weakest and what best" it would, perhaps, soothe an anxious author and help him in his future work.

A book must go to Sedgwick, though no hope went with it. Him Darwin knew too well to expect any encouragement for a theory that ran counter to Genesis. Long years ago, when as a boy he tramped with Sedgwick the mountains of Wales, he had learned that the Bible was a very personal message from God to Sedgwick and could not, therefore, lightly be put away.

With Hugh Falconer, the hot-headed Scotsman who knew fossils backwards, Charles could be gay and inconsequential in the note he sent along with the book: "Lord, how savage you will be if you read it and how you will long to crucify me alive!"

Thus lightly he wrote, although the fall days were passing dismally with him. For five weeks sickness shut him in the house, kept him away from his desk and forced him to watch his thoughts whirl round and round the one idea: What will be said about my book? But it is doubtful whether at any time he got the faintest notion of the wild, howling, lashing, boisterous storm his book was to let loose in the world.

9

There was joy in the house of Darwin. Hooker was converted, had accepted the theory whole-heartedly. Lyell, too, had swung around, according to Hooker, though "judging from his letters to me he is deeply staggered." Carpenter, the wise physiologist and a

power among men, had written that he would review the book and fight for it. Watson, famous botanist, exclaimed, "Your leading idea, Natural Selection, will assuredly become recognized as an established truth in science."

Best of all, the mighty Huxley was "sharpening up his claws and beak in readiness" to fight for Darwin. He was even prepared "to go to the stake," if necessary, for the theory laid down in "The Origin of Species."

"We shall win," Charles told Emma. "In the long run we shall conquer. Fifteen months ago, as you know, I had awful misgivings; and thought perhaps I had deluded myself. Now I am content."

"You should be, Charles. The book is a real success."

"You're right. The thing has exceeded my wildest hopes. I sometimes fancied that it would be successful, but I never built an air castle of such success as it has met with."

Thus Darwin bubbled over and set a confident face to a rosy future. But a man whose spirits could rise and fall as quickly as his should never have written a book. Close on the heels of this early praise came a gust of cold air. Herschel, the big man of astronomy, called Darwin's theory "the law of higgledy-piggledy," the meaning of which phrase was not clear, but "evidently it is very contemptuous." Charles was instantly crushed by this "great blow and discouragement."

And a letter from Sedgwick, the friend and master in geology, from whom Darwin expected kindness and consideration brought gloom and wretchedness to Downe House, for Charles had not yet learned that trampled religion forgets all gentleness.

"I have read your book with more pain than pleas-

ure," the geologist wrote. "Parts of it I laughed at till my sides were almost sore; other parts I read with absolute sorrow."

If a friend could write in this vein what would those stranger-ministers find to say? Here was the first hint of the real storm that was brewing.

From America came the cheerful word that Asa Gray was defending the book because he believed in it. It didn't matter if the great fish expert, Agassiz, denounced the theory on the ground that there was no such thing in nature as variety! Gray could, and did, laugh that foolishness out of court.

The sneering bitterness of Richard Owen was harder to bear. He, once a friend and counselor, had now turned enemy. That is not too strong a word. After the appearance of "The Origin of Species," he seemed actually to hate Darwin and his two close friends, Hooker and Huxley. Something snapped in Owen's head when he first looked into the book and thereafter he went around frothing at the mouth. Friendship and decent scientific argument were forgotten, and he never could find words quite bitter and cruel enough to phrase exactly what he thought of the theory and its author.

What was the secret of this attack that grew in volume month after month, swelling into a great tide of hostility, threatening to sweep Darwin and his work into oblivion? Why the bitterness and derision that sprang into life in Tennessee, sixty-five years after the publication of Darwin's idea? Why did Lyell hesitate, and in the end never come out flat-footedly for evolution?

Lyell confessed that he shuddered at the thought that "man is descended from monkeys." Is not that the answer? Pride? And pride in what? In a legend, not

original with Europe or the Hebrews from whom it was adopted, that God with His own divine hands had molded man from clay and sent him forth to fall into a state of wretchedness and depravity. Theologians could accept man's fall with its obvious criticism of God's power; but they could not accept the magnificent spectacle of an animal climbing up out of the muck and slime to stand fearlessly on his two feet in the presence of overwhelming mysteries. The vanity that, wrapping itself like a flame around man's mind, made him dare to face the omniscience of God, rose darkly between him and the ancestral tree up which he had crawled. To those nineteenth-century priests, and to some who are still alive in the world, a smaller and weaker God means a greater and finer man.

10

Charles Darwin, with a shawl around his shoulders, came down from his study to join Emma in the living-room.

"They're not a bit nice ones today, Charles," Emma said, without looking up from the pile of clippings that she was sorting.

"No matter," Charles answered, "let's have them."

"Oh, why do they say such cruel and false things!" Emma cried. "Here's one that declares you have proved might is right, and therefore Napoleon was right and every cheating tradesman is right. . . . You can laugh if you like, but I think it's just spiteful and mean. Here's one from Professor Henslow that's rather nice. He says he cannot go as far as you do, but he can give no good reason why he shouldn't."

"Good for Henslow. That's fine. Much better than I expected. I thought he'd be after me hammer and tongs. Better than Sedgwick, eh? But poor old Sedg-

wick is just rabid with indignation, in spite of his noble heart."

"Here's an article in the Edinburgh Review. It won't do you a bit of good to read it so I'm going to put it away where you can't get your hands on it."

"Let's see it, Emma, please. Every review is helpful no matter how silly and cross. . . . Yes, this isn't exactly nice, is it? Now I wonder. You know, I'm sure I see Owen's hand in this. Undoubtedly he wrote it. . . . It's clever, Emma, but malignant."

"That's just what I say. Only a mean-spirited man would have written it."

When Charles had finished the review he rose and drew his shawl closely about him, as if through the spring sunshine a cold wind had cut him. His shoulders drooped, and the lines in his face were suddenly very deep. He stood for a moment looking about him, and for once those powerfully observant eyes of his saw nothing. Was he dreaming of the days when he and Owen had first met, and a quick, warm friendship had sprung up? Or was he peering into the future and realizing, for the first time, the force of the opposition he had to face? At the door he paused and looked back at Emma, his ready smile giving the lie to the pain in his eyes.

"I see plainly," he said, "that it will be a long, uphill fight, and I must buckle on my armor. As for this review of Owen's, it probably will be very damaging. There is a good deal of bitter spite in it, and he has scandalously misrepresented many parts of the book. He even misquotes some passages. It is hard to forgive that kind of attack." He swung into the hall, but paused again to say:

"It is painful to be hated in the intense degree with which Owen hates me."

## II

There was a rumbling and muttering out of all England. Evolution was the topic of the day. The young people were largely for it, as neither the past nor the future seemed quite so sinister and mysterious if one held to evolution as a guiding star. But the middle-aged were so violently against it that no logic or argument could reach them, and only in the bitterest of personalities could they express their abhorrence of the whole subject and of anyone who supported it.

These conservatives believed in their divine origin. Their creed taught them that man was dominant through his close allegiance with God, who had breathed into His supreme handiwork an immortal soul. Hence they refused to believe that man had won to his high place through a million years of struggle, and had only recently burst out of the jungie to set his foot decisively upon the necks of his brute brothers who had fallen before his cunning.

But the tide of evolution continued to rise. The younger generation, mad for anything new, was grabbing it up and rushing straight to hell. Graybeards and dignitaries must get in the way of this stampede and with flaming texts open the eyes of these boys and girls and show them the precipice of damnation toward which they were racing.

"Save souls and crush evolution," was their slogan. No better chance for doing both of these things could they have found than at the meeting of the British Association for the Advancement of Science held at Oxford, beginning June 28, 1860. Oxford was conservative to the point of stupidity, as solid as the seven hills of Zion. Was it not likely that God had reserved for Oxford the honor of destroying this new monster,

which after all was only the same old devil with a different set of false whiskers?

Wilberforce, Bishop of Oxford, was picked as the man to deal out the death sentence. He was eloquent and keen, strong in the faith, and he told his friends that he intended "to smash Darwin."

12

Saturday, June 30, 1860, was a day that Wilberforce never forgot, but it was one of which he did mighty little talking after the smoke had cleared away. Everybody and his wife were present at that science meeting. There was such a crowd that the library had to be pressed into service, and into this room a thousand people packed themselves. Undergraduates probably made up the bulk of the audience, but there were also gray-bearded ministers and catch-as-catch-can scientists present, and there were many women, drawn by their confidence in the crushing power of "Soapy Sam," the Bishop of Oxford. There were not enough chairs, so many of the audience sat on the window-ledges and craned their necks in their eagerness to hear and see.

John W. Draper, author of "The Intellectual Development of Europe," read the main paper—"flatulent stuff," according to Hooker.

On the Thursday previous, Owen, an authority on anatomy and therefore confident that no one would dare to contradict him, had made the statement that the gorilla's "brain is more different from a man's brain than it is from the brain of the lowest apes." Unfortunately for him, Huxley was on hand to "flatly and unequivocally contradict the statement." Darwin's bulldog hadn't meant to attend the meeting; but he got dragged in, and once there he was, as ever, ready

to fight. This skirmish with Owen set the temper of things for the Saturday gathering.

When Draper sat down, little fellows began to bob up here and there, each convinced that he could easily knock the wind out of Darwin. But as each surged into a religious discussion, the young gentlemen in the audience shouted him down. Then Wilberforce stepped forward.

The bishop had not read Darwin's book, but Owen had coached him, and he sailed into his speech with a fine air of judicial reasoning, in which fact and fancy played an equal share. Warming up he sidestepped science rather neatly and gave his attention to the religious emotions of his hearers. The women responded by becoming frankly hysterical over his eloquence.

Carried away by the inspiration of the moment, Wilberforce turned to Huxley and asked:

"Is it on your grandfather's or your grandmother's side that the ape ancestry come in?"

The ladies screamed with laughter at such wit. But the bishop could not end on so light a note, and with great gravity he stilled the snickers by announcing as final that "Darwin's theory is contrary to the revelations of God in the Scriptures."

That should have settled it, but unfortunately for the bishop, certain of the younger generation wanted to hear what Huxley had to say. They called so insistently that at last Huxley rose to reply. The world still reads and chuckles over his famous retort to the bishop's question:

"I asserted, and I repeat, that a man has no reason to be ashamed of having an ape for his grandfather. If there were an ancestor whom I should feel shame in recalling it would be a man of restless and versa-

tile intellect who, not content with success in his own sphere of activity, plunges into scientific questions with which he has no real acquaintance, only to obscure them by aimless rhetoric and distract the attention of his hearers from the point at issue by digressions and appeals to religious prejudice."

Those words caused a hullabaloo. Young men shouted. Women screamed in earnest now, and Lady Brewster fainted. Darwin smashed? On the contrary, the smasher himself was smashed. Lady Brewster might faint, and the other ladies be inexpressibly shocked, but monkeys for ancestors had come to stay.

13

As Emma read aloud Hooker's account of the Oxford meeting, Darwin felt that his cause, defended by his friends, had triumphed. Not soon again would a bishop attempt to overawe experts in their own field. This much he could gather from Hooker's words, but neither he nor Emma was blind to the fact that the fight was still on.

Ministers everywhere denounced Darwin. Nor did they content themselves with hatred of his theory; they carried their hate over and poured it out on the head of the author. Here was a strange picture upon which the world still stares in amazement: the kindest man in the world, full of generous impulses and with a real love for all things that live, was described as a monster, a fiend seeking to destroy the family, to undermine affection, to blot out the beauty of religion. He was an atheist who sneered at God, he was a wretched apostate, he was nothing less than a deep-dyed villain—and a stench in men's nostrils.

Lamarck had not been so castigated; Charles' grandfather Erasmus had been tolerated and even praised.

What was the reason for this extreme bitterness? Emma could answer that question in her own way and did:

"You have put God farther away from them."

Charles probably felt that she was right and that the removal of God had been forced by his logic. Henslow's words, "I cannot go as far as you do, but I can give no good reason why I should not," makes the whole fight perfectly clear. Small minds, beaten by Darwin's data, fought furiously to ward off conversion.

So the ministers in England and America cried out against evolution, and evolution went steadily on its way. "The Origin of Species" was translated into German, and the German scientists accepted it. It was translated into French, and the young students of France would talk of nothing else. Translations into all the languages of Europe were rapidly made, and eventually the theory found its way into the Orient and was turned into Chinese.

It must have seemed strange to Emma Darwin to sit opposite her husband, now turned sixty and bearded, and realize that he belonged, not to her, but to the world. She was still the housewife, the rather heavy, good-natured woman into whom the beautiful Emma Wedgewood had metamorphosed—who had found it pleasant to give up society, theaters, and music for companionship with the man she loved.

Charles, hearing his name ring across the continents, was glad, and he expressed his joy in childlike phrases to his friends. But there was no conceit and no boasting. At no time did he think his mentality was superior to that of others. His success he said was due to hard work, "dogged does it," to powers of observation that were, perhaps, a little better than the average and to opportunity. Not even to Emma did he suggest that

maybe after all he was a mighty clever fellow. He was amazed when men praised his writing, because he had often said, "If there's an awkward way of saying a thing I'm sure to find it." Was all this merely an assumed modesty? None of his family thought so, and they're the ones who can pick flaws in a great man's armor.

14

Charles Darwin was fifty when "The Origin of Species" appeared; he was sixty-two when the "Descent of Man" was published. The next year he put out his book on "The Expression of Emotions in Man and Animals"—a work for which all his life he had been gathering data. Three years later came "Insectivorous Plants," the next year, "Cross and Self-Fertilization," to be followed by "The Different Forms of Flowers on Plants of the Same Species." In 1880, he published "The Power of Movement in Plants" and in 1881 appeared his epoch-marking book, "The Formation of Vegetable Mould Through the Action of Worms."

Is not that a list for a man nearing seventy?

The worm book is his last. There were other problems he was anxious to tackle, but he realized the time was too short, and he sighed for the energy and the confidence in an extended future, that were part of his youth. Now he could only putter around with small things and hasty experiments.

Yet life still beat strongly at Downe House. All the world wrote him, and every letter got an answer, kindness thus radiating from this country home no matter how outrageous and silly the unknown correspondent. Again and again he was asked about God, and over and over Darwin said, sorrowfully, "I don't know."

Never a man lived who had less desire to meddle with his neighbor's creed. He was an agnostic, but he was a gentle, kindly, open-minded agnostic, with whom even his wife could not quarrel.

Emma was religious; all her life she had been religious, and she had looked sadly upon Charles's work, which seemed to "put God farther away." Now when small and spiteful letters came accusing Charles of being an infidel, an atheist, and a blasphemer, she would look at her husband with a shadow of perplexity in her eyes and say:

"What have you done with their God, Charles?"

How could he answer that question? He had done nothing with God. He had destroyed a legend, but he had left the source of all life, the Creator, untouched. He could tell Emma that gods grow old and die; that the gods of Persia, of Egypt, of Greece, of Rome had grown old and died; that the god of the Hebrews might, also, grow old and die; but that back of universe upon universe some unimaginably mighty Spirit must live and rule, and that no little question or answer of man can destroy that Omnipotence.

Never a man lived into whose religion so many busybodies tried to pry. They assailed him from all countries in all languages. But gradually these attacks died down, as the name of Darwin came to fill the world, and in place of abuse, honors were heaped upon him. Even Cambridge fell under the spell of his genius.

What was the greatest day in Charles Darwin's life? He himself said it was that December 27, 1831, when the Beagle carried him out to sea on the first leg of his five years' voyage. Or was it that day in November, 1859, when "The Origin" was published? Or was it in June, 1860, when his theory triumphed at Oxford? Or was it on that November 17, 1877, when Cambridge

forgot its high-and-mightiness and suddenly turned human?

15

No honorary degrees from Cambridge was the rule and precedent. Honors were showering upon Darwin, yet Cambridge, which was his school, had nothing for her most distinguished son. Let us do something then, said Cambridge, and prove that we know a great man when we find one.

That was why the Senate House at Cambridge was packed on November 17, 1877. Undergraduates were everywhere, clinging like acrobats to window-ledges and draping themselves around statues; a noisy, joking lot of youngsters, out to see a fine show and get a glimpse of a great man who had once cavorted through these same halls.

A group of dignitaries entered. One of them was tall, bald, with a full beard flowing white against the red cloak thrown over his slightly drooping shoulders. He was recognized, and a great cheer rang through the room. What did Darwin think in that moment? Almost fifty years ago he had sat where these cheering boys are sitting, and no dream of his present greatness had marred his joy in life. Did he remember the kindly Henslow, the wise Sedgwick, since turned bitter and "laughing till his sides ache"? Upon what had that friendship been wrecked?

There was the answer, dangling and screaming before his eyes, as the youngsters in the gallery swung a monkey over the heads of those below. It was against that and the suggestion it carried that Sedgwick and his kind had fought.

There was a long-winded harangue, in which the undergraduates hadn't the slightest interest, and then

Darwin stood with clasped hands before the vice-chancellor, who muttered a few words in Latin. Everybody crowded around Darwin to shake hands, and the boys upstairs and down made a great racket. And afterwards Emma "felt very grand walking about with my LL.D. in his silk gown."

16

It was the last of his great days. He had a bit of work with earthworms to finish up and then—

Sickness interfered almost constantly now, but some way the book on soil and worms was finished, and he and Emma did their last bit of proofreading, sent the sheets to the printer—and a life's work was done. Darwin must leave to younger men any problem that called for extended research.

He and Emma were now alone in Downe House, for their children were out in the world. The sons were married, and Emma and Charles often told each other how well off they were in daughters-in-law, for it would have been so easy "for our sons to have married very nice wives that would not really have adopted us."

Living in their children? What else is there for very old people to do?

Spring, 1882, came to England, and on March 17, Charles Darwin was out in his orchard watching the little green things breaking into life.

Two days later, while his son and daughter supported him, he smiled and said, "You are the best of dear nurses." And a little later he was dead.

17

Does Darwin's theory still live? It can be answered categorically that evolution still lives, sturdier and more firmly based than ever.

But natural selection does not stand today as strongly as it did fifty years ago. That one idea was not Darwin's big gift to man. What he gave was a light in darkness and an escape from age-old prisons. Life is freer, and finer and broader and more intense because such men as Lamarck, Faraday, Koch, Pasteur, Lister and Darwin worked for the pure joy of knowing, and with no shadow thrown across their dreams by a desire for personal gain or a mean fancy that success could be calculated in dollars and cents.

*Chapter Twenty-five*

# GREGOR MENDEL

GREGOR MENDEL, born 1822, an Austrian peasant boy, entered the monastery of Brünn and remained there all the rest of his life. His whole world was confined to the bit of ground that was shut in by high walls. His contacts with the life of the old town were purely religious and official. Europe was in a fever of scientific discovery. Pasteur was waging his battles in France; Lister was teaching humanity in Scotland; Darwin was preparing his thunderbolts in England; Helmholtz and Hertz were delving mightily in Germany, where Koch was also at work; Asa Gray and Agassiz were working in America.

All of this activity was seething under Mendel's nose and there's no reason to believe that he knew anything about it; at best, his ideas of this scientific turmoil must have been vague and uncertain. Brünn, itself, was cut off from the great world, and Mendel was cut off, by the vows of his order, from Brünn. He had none of the scientific friendships that were so valuable to Darwin, to Pasteur, to Koch, and he had no training for research or analysis.

Few men, smitten with the mad desire to know, were ever placed in so deplorable a situation. Friar Roger Bacon had access to what learning the age provided and Copernicus had the advantage of study in several schools and maintained his contacts with other scientists. Mendel's whole life, from early boyhood to death,

belonged to gray walls and the bit of garden he tended.

Gregor was a peasant. That is to say, he came of a family that spent its life trying to make things grow. Before he entered the monastery he worked in the fields, scraping the soil with a wooden plow and sowing the seed by hand. He had watched the seed sprout, grow tall and ripen for the scythe, and it is probable that he asked himself even then: "Why does wheat always grow wheat and onion seed, onions?"

Darwin spent five years ransacking the world in search of data to prove one theory. Mendel could not do that; but his genius was too bright to quarrel with the tools at hand, and so well did he use the few rods of land that were available, that he went far toward destroying Darwin's idea of natural selection. How amazed Darwin would have been had he known that in the little city of Brünn an unknown monk was at work carefully removing the foundation from his magnificent edifice!

2

It is doubtful if Mendel ever knew much of Darwin and it is reasonably certain that he never saw a copy of "The Origin of Species." He had no idea of proving anything when he set to work with his tall and short peas. He had a hankering to know and in his limited world the only way he could get information was by making experiments. He had no scientific training so he trained himself; anyway there was no established technique for the work he was to undertake, and he found it necessary to learn everything from the ground up.

His question was this: What will happen if two varieties are crossed? He had to take great care to keep insects away from his experimental plants and he had

to be wise enough to shut his eyes to all except the one trait he was studying. He took tall and dwarf varieties of the common pea and crossed them, centering his attention on this one characteristic. The results in the third generation amazed him. He tried again with red or white flowers, with yellow or green seeds, with round or wrinkled seeds.

Each time the results were the same. At last he could prophesy, with almost mathematical accuracy, the results in the third generation. But Mendel was a careful soul and he continued for eight years working over his plants, trying them this way and trying them that—proving, proving his conclusions, until he was satisfied that he had hit upon a law, a basic statement of fact.

Then he prepared a short account of his experiments and the astonishing results he had observed. This paper, more iconoclastic than all the volumes of Lyell and Darwin and Huxley and Spencer rolled into one, was obscurely published in the Proceedings of the Natural History Society of Brünn, in 1865.

However, when this paper appeared, nothing happened. Brünn was off the beaten track; the members of its Natural History Society were unknown men—who have remained unknown. They were merely a little group of country professional and business men who were, in a half-hearted, amateurish way, interested in small questions of science. There was not a man among them able to read Mendel's paper and realize that a revolutionary classic was in his hands.

No word of this paper went out from Brünn, and Mendel, who had hoped and dreamed, continued to work in his garden, waiting for some friendly voice to speak to him from out the great world of science. But no voice called and after seventeen years, Mendel, now Abbot of his monastery, left an ungrateful world.

No one knows what occupied him after his paper was published or what experiments he carried on. He wrote one account of his work—and it fluttered down at his feet, dead. He never tried again. Luckily the crux of his message remained and could not forever be lost to the world.

3

Brünn's Society of Natural History at least gave its records a permanent form. Scientists, looking for enlightenment on the general subject of evolution, found their way into the dust-covered journals of Brünn's Natural History Society. Hugo de Vries, of the mutation theory, C. Correns and E. Tschermak, searching out the mysteries of sex and hybrids, each, independent of the other, found this paper written by Mendel and ignored by science. Each found, too, that here was a strong and steady light, illuminating one of life's most mysterious jungles. Each of them, realizing that he had stumbled across the work of a genius, heralded his discovery to the ends of the earth.

Mendel, sleeping quietly in the cemetery of Brünn, was thus, after thirty-five years, raised to the very pinnacle of fame. No stranger episode than this occurs in the whole story of science. Cavendish made discoveries that were hidden for fifty years; but they were hidden only because his papers were not published. Roger Bacon is credited with knowledge far in advance of his age, but the bulk of his work was lost.

But here is the point that makes Mendel's position unique: though his paper was thirty-five years old when it was found in 1900, science had not yet moved forward to meet it. The efforts of trained scientists through all those years had failed to carry them as far as Mendel had gone.

All over the world men read Mendel's paper and an army of students repeated his experiments, testing them to see if he knew what he was talking about. Everywhere they found he was right; he had been accurate and he had set down no more than the facts. Today, after nearly sixty years, Mendel's law still stands stronger than ever, upheld by research in the allied subjects of sex, cytology, embryology, albinism, genetics, eugenics and heredity.

4

Francis Galton, not yet a "Sir," but a well-known explorer and student of weather, was working on heredity at exactly the same time Mendel was carrying on his quiet experiments. Galton could not be satisfied with an obscure plant for his experiments and he took into his laboratory nothing less than man himself. He collected data with great diligence and enthusiasm and in due time announced his two laws:

First, the average contributions made by parents, grandparents, great-grandparents, etc., are definite and tend to diminish in a precise ratio according to the remoteness of the ancestor. The parents, under this law, contribute one-half to the inheritance of the child; the grandparents, one-quarter; the great-grandparents, one-eighth; the great-great-grandparents, one-sixteenth, and so on back to the point where it would be hard to say who or what contributed the last indescribably small, but important fraction.

Second, in some obscure way nature tends to approximate either upward or downward to the mean average of the stock. "The ablest of the children of a few gifted pairs," says Galton, "is not likely to be as gifted as the ablest of all the children of a great many mediocre pairs."

Galton's way of approaching his subject was as different from Mendel's as Aristotle's was from Galileo's. Galileo dropped his weights of unequal size and timed their fall; Aristotle took somebody's word for it. Galton gathered statistics, human records; Mendel went to Nature and asked her to tell him exactly what she did. Galton's laws are still highly hypothetical; anyone can repeat Mendel's experiments and get the results he got.

Mendel took tall peas and crossed them with a dwarf variety. From this crossing he got descendants that were all tall, or even a little taller than the tall parent. Then he took the seed of these tall plants that had tall and short plants for parents, and grew another generation and now he had tall and short plants, with almost exactly three times as many tall as short. Then in the next generation he found a very surprising thing: the seed from the dwarfs produced only dwarfs but the seed from the tall produced both tall and dwarf. Out of six of the tall plants two would give tall plants and would never grow anything else; but the other four would give tall and dwarf in the proportion of three tall to one dwarf—and this ratio was maintained through all succeeding generations.

Here was a clear solution of a problem that had bothered men ever since they began to breed domestic plants and animals. What were known as "throw-backs" were always getting into their stock and could only be explained by the use of something like Galton's first law. Mendel showed that these "throw-backs" must occur, in definite proportion, wherever the parent stock was what is now known as "heterozygous." That is, the tall plant in the second generation that could give both tall and dwarf was heterozygous. The tall plant that gave only tall descendants was pure, "homozygous,"

and would never, as long as it was kept pure, give a "throw-back."

5

This ability to breed a pure type, by careful selection and observation, is the central truth in Mendelism. It is difficult to breed pure for a group of traits or characteristics, but any one trait can easily be secured. For instance, a horse bred to a chestnut color will be pure in this respect and a strain can be selected that will never produce anything except chestnut. Also pacers can be bred true in exactly the same way as the dwarf peas were bred true since both pacing and dwarf are "recessive" traits. This means that if a pacer and a trotter are crossed, the off-spring in the first generation will be a trotter, since this trait in horses is "dominant" to pacing; but if the descendants of the first pair are inter-bred, the third generation will show either a pacer or a trotter. If a pacer, and if bred with a pure pacer, the descendant will be a pure pacer. Experiments with animals that produce only one offspring at a time will, of course, be difficult and involve long periods. But the law holds good for any trait upon which attention is centered.

6

Work on heredity, after Mendel's paper was brought to light in 1900, took on some sort of sense. Men knew what they were looking for and how to go about their problems. Mendel showed, and others since then have confirmed his idea, that heritable traits were to be sought in the sex cells of the male and female. These cells are known as gametes and when the spermatozoon is introduced into the ovum, a zygote is formed.

The spermatozoon is a little cell with an active tail

which gives it a kind of locomotion. Upon fertilization, the head and a bit of the tail of the spermatozoon enter the ovum, which is a much larger cell, totally lacking the power of motion. The instant the spermatozoon forces its way into the ovum great activity occurs in the zygote, and it rapidly increases in size by the multiplication of cells. As yet nobody knows why this happens. Probably it is the result of chemical action too illusive, so far, for man to follow.

These two cells, differing as they do in appearance, have some things in common. Each contains a certain number of chromosomes. In human beings each sex cell, male or female, contains forty-eight. With few exceptions each species has a definite number of chromosomes. The smallest number as yet found is in the threadworm of the horse which has only two. Science has centered a good deal of attention on these easily colored segments, because they probably carry the secrets of heredity.

At any rate, heredity obviously belongs to the sex cells—and to nothing else. These sex cells are segregated very early in the development of the embryo. Thereafter they seem to form no integral part of the organism as a whole. The cells of heart, lungs, etc., all cooperate and have, probably, a distinctive interrelation and interdependence. In other words, the organism simply holds the sex cells as a trustee holds money. So it seems that no trait can be passed on to the next generation that is not in the sex cells.

If this is true, why aren't all the animals of any given species exactly alike? Mendel gives the following answer: In nature cross-fertilization constantly occurs and has been occurring for a long, long time. The result is that there is hardly any plant or animal that is homozygous; almost all of them are heterozygous and

will therefore, according to Mendel's law, throw off a certain number of descendants distinctly varying from the pure type. According to Mendel, the variations upon which Darwin built his theory of natural selection are the results of heredity and in no way involve the idea of chance or innate change.

7

Then how about evolution? Natural selection wasn't evolution: It was merely Darwin's idea of the way evolution worked. Once upon a time men thought that the earth stood still and the sun moved around it. Now they think the sun stands still, relatively, and the earth moves. It makes no difference which you believe, the sun still appears in the east and vanishes in the west. In the same way, evolution, probably, is a fact though theories about it may change from century to century.

Mendel hasn't in the least robbed us of our right to claim an ancestry of tree-living creatures closely resembling monkeys, but the means by which we became something else may remain forever unknown. Mendel's work, and the work of those who followed him and are still following him, indicate that natural selection won't do. In its place, therefore, they are suggesting "change of habit." E. W. MacBride says: "Acquired habits tend to become innate." And again he writes: "Change of habit reveals itself as the great driving force in evolution." "Organs originally developed in response to the stimulus of a new environment—"

Surprising things happen when new habits are induced by change of environment. A pair of adult salamanders will normally produce thirty or forty offspring which have gill slits and long gills and which live in the water for six weeks before they change into land animals. If they are put in a cold, dry environ-

ment, the number of young will decrease. If the climate is colder and dryer, still fewer young will be born and they will be more highly developed at birth. If these young are also kept in the cold, dry air, they in turn will have fewer young; and if the experiment is continued, animals will result that give birth to only three or four young having the merest stumps of gills and never entering the water, but taking up at once the adult form of life.

Of course, more experiments are needed and since Mendel has shown the hereditary nature of variations, embryologists and cytologists are hard at work building up a new theory for evolution.

8

Mendel's law is as certain for human beings as it is for plants. The real question is: what use can be made of it among a free people? Not much, probably, as long as wisdom lags behind personal liberty.

Still there are certain things that may be helpful if they are kept in mind. The sex cells are, to all intents and purposes, immortal. That is to say, the sex cells that appear in the embryo are, as far as scientists have been able to discover, exactly like the cells that combined to form that embryo. Naturally this gives an almost unbelievable endurance to characters, good or bad, that were carried by the parental sex cells.

Whatever, then, can become inherent in the sex cell will be passed on to the child, but with an exception. If the trait is recessive, as the short pea was recessive to the tall in Mendel's experiment, it will appear only in one out of four, or about that. There are about thirty human abnormalities, including presenile cataract and claw hand, that are dominant and will thus show themselves in descendants. Some families

are afflicted with a tendency to bleed, hemophilia, and this abnormality is dominant with the strange condition that in such families there are generally a good many more men than women. This characteristic is known as a sex-linked abnormality.

Science has also traced the surprising behavior of color blindness. A color-blind man and a normal woman will have children all of whom are normal and the sons will be unable to transmit color blindness. The daughters, however, when married to normal men, will transmit it to half of their sons. If they marry color-blind men, they will have color-blind daughters. Then if one of these color-blind daughters marries a normal man, the sons will be color blind. The daughters will be normal but they in turn will have color-blind sons.

Experiments along Mendelian lines, coupled with statistics, have thrown light on the question of hereditary disease. There is nothing to indicate that disease, brought on by environment or work, is in any sense hereditary. Diseases due to microbes are confidently believed not to be hereditary. Frequently infection may occur before birth and this might lead the uninformed to think that the disease had been carried in the sex cells. Certain forms of nervous disorders and feeble-mindedness appear to be hereditary and may even be "dominant" characteristics. In general it seems safe to believe that disease is not carried in the sex cells.

9

Mendel, delving in his quiet garden at Brünn, uncovered the truth that we are in a very real sense a part of every one of those men and women who form the long procession of ancestors that reaches back into the dawn of time. The germ-plasm carries with it strange forces and weird traits that served their pur-

poses when the jungle was a fierce battlefield and one lived in the presence of swift death. But it brings, also, emotions that have melted to tenderness and instincts that have discovered God and happiness in life.

*Chapter Twenty-six*

# HERTZ

FARADAY, a hundred years ago, found the key to Nature's electrical stores and swung wide the door, thus opening to mankind a new world and a new age. But even his genius could not dream the changes that one century would bring. Almost at a stride, life moved upon the telegraph, the ocean cable, the telephone, the phonograph, electric power, electric heating, electric lighting. This invisible and terrible "fluid" was at last tamed and put to work.

What was there left to be discovered? New uses, but probably not new properties, new manifestations. James Clerk Maxwell, captivated with Faraday's matchless logic, sought mathematical proof for all those wonder words. And found it. Maxwell turned out clear and convincing formulæ, and demonstrated the accuracy of Faraday's statements.

But Maxwell was more than a juggler with formulas. As he labored with his equations, his imagination showed him beautiful deductions, and he realized that this phenomenon, into the heart of which Faraday had penetrated, had disclosed only a few of its mysteries and still held vast possibilities for research. At a time when men were saying, "Electricity is licked, and all of its powers are known," Maxwell was trying to identify light and electrical energy and insisting that his theory proved that electro-magnetic disturbances are propagated as waves.

With him these waves were theoretical, but he believed mathematics proved that they must exist. He died at the age of forty-eight before the laboratory showed that he was right.

2

Maxwell was twenty-six years old and a famous scientist, when Heinrich Rudolph Hertz was born in Hamburg in 1857. It could hardly have occurred to the Scottish genius, at that time professor of natural philosophy at Aberdeen, that the future of his two great theories about light and electric waves rested in the hands of a red-faced German baby, sweating under innumerable blankets in a Hamburg cradle. And yet these two, one by cold mathematical formulæ and theory and one by brilliant experimental demonstration, were to give the world a new idea of light and a new phase of electric power out of which was to come the wireless telegraph and radio.

When young Heinrich had finished with the Hamburg schools, he thought he would like to be an engineer. It was this ambition that took him, a boy of twenty, to Munich in 1877. Less than a year of study was enough to take the idea of engineering out of his head. A year away from home, meeting the world on his own two feet, had made a man out of Heinrich, and now he knew exactly what he wanted to do, and he set about doing it. Henceforth, he was devoted to physical science.

In the fall of 1878 he was in Berlin, listening to the lectures of the great von Helmholtz. He had prepared for this course during the previous winter and summer by reading the works of Laplace and Lagrange. Nothing light and airy in either of these authors. Even the best of mathematicians find Laplace rather more than

a mouthful and are obliged to spend hours in difficult calculations to grasp a point that Laplace sets down coolly as self-evident!

That was the kind of preparation Hertz had when he began listening to Helmholtz. Almost immediately he was able to plunge into original research, and in 1880 he won a prize with his paper on "Kinetic Energy of Electricity in Motion." You can imagine, in the light of this statement, that there was little skylarking in Heinrich's life. He seems to have been born old, and almost from the first he was overtrained and burned himself out at an early age.

3

Soon after entering Berlin, Hertz's attention was called to Maxwell's electro-magnetic theory, and Helmholtz tried to persuade him to start laboratory work upon it. But this he did not do at the time, for the very good reason that he could think of no way of going about it. In that he was like all the other students of electricity who had run across Maxwell's idea. The theory sounded fine, but how to test it?

Doubtless the thought lay germinating in Hertz's head, bound some day to burst into life. It was at Kiel, in 1883, that he first began serious work on the problem, but nothing of importance was discovered then. Two years later he was professor of physics in the Carlsrühe Polytechnic, and there in his laboratory he again tackled the Maxwell problem.

This time a brilliant stroke of genius pointed the way and he was successful. When those minute sparks appeared in his detector, Hertzian waves were demonstrated, Maxwell was proved right and the first step toward wireless and radio was taken.

The simplicity of Hertz's experiment was the most

baffling thing about it. Why had no one else thought to do just what he did is as puzzling as why no one before Faraday guessed that movement was necessary in electro-magnetic induction.

What Hertz did was this: He took two zinc plates to which were attached rods, ending in brass balls, highly polished. The rods were in contact with the poles of an induction coil. Naturally, when the plates were charged and the two balls brought close together a spark would leap across from one to the other. It was this leaping of the current back and forth, as proved by the sparks, that Maxwell said would send the electric waves into the air. Hertz's task was to detect these waves and prove that they were escaping.

He made a detector of copper wire bent into a circle, the ends of which were equipped with balls and a screw mechanism, so that the distance between the balls could be regulated to a nicety. When this detector was held near the zinc plates and the sparking brass balls, minute sparks appeared at the ends of the circular wire. What caused those sparks? Electric waves released by the vibrator, Hertz said, and now all the world agrees with him.

Not much to this experiment, yet when the wireless crackles across a stormy sea in a directed effort to save life, we can thank Heinrich Hertz for that experiment. As we sit comfortably at home and listen to song or orchestra or prize-fight over the radio, our entertainment is the work of Hertzian waves.

## 4

This story of Maxwell and Hertz is not meant to take any credit from Marconi and de Forest and Armstrong, whose inventive genius has brought wireless and radio into practical application. But they have

worked with the waves that Hertz discovered, and without him or another like him no wireless and no radio would be in the world today.

Nor is there any intention to slight the work of the great Thomas A. Edison. Now and then you will hear someone credit Edison with the discovery of these waves, and the sad part of the story is that Edison came within a hair's breadth of making the discovery. In 1875 Edison noticed something queer as the result of electric sparks. He didn't know what it was he had found, but he called it "Etheric Force."

Twelve years later Hertz found, by deliberate experiment, the same thing. He spent the rest of his life studying the waves, charting their course, their length, their reflection and refraction. He put himself on intimate terms with this phenomenon, and bored his way into the heart of it. It is not on record that the idea of capitalizing his discovery ever entered young Hertz's head. He was in search of scientific truth, and more than satisfied if he found here and there evidence that his feet were set in the right way.

Can this be held as a criticism of Edison? Not at all. He was in search of other things and only incidentally stumbled upon his "Etheric Force." It is a tribute to his powers of observation and reflection that he noticed it at all. If he had remembered Maxwell's theory, the relationship might have occurred to him and roused his interest to further deliberate research. But this connection was never made in his mind. Indeed, so far was he from understanding his "Etheric Force" that when, six years later, he took up the problem of telegraphic communication with a moving train, he made no use of the Etheric Force and worked out a system depending entirely upon the current ordinarily used in telegraph wires.

## 5

Hertz found out some interesting things about these newly discovered waves. For instance, they would pass readily through the wall of a room, but they were stopped by a large plate of thin metal. By using mirrors he found that the waves were reflected and refracted, and by moving his detector to various spots between the mirror and the vibrator he worked out the length of the waves. He also computed their velocity and found it practically equal to light.

In every respect, Hertz found that these waves acted and reacted as do light waves. These conclusions, according to Helmholtz, went far toward proving that ordinary light is merely electrical vibrations. This you remember was part of Maxwell's theory. Thus Hertz rose as a champion to prove, in his laboratory, the accuracy of mathematical conclusions.

Hoping to discover other properties of electricity, Hertz, after removing to the University of Bonn, where he went as professor of physics in 1889, began the study of electric discharges in rarefied gases—and he narrowly missed the discovery of X-rays.

Here the story of his brilliant researches ends. On the first of January, 1894, he died at the age of thirty-seven.

## 6

Hertz left behind him a new toy with which science could play, and almost at once experiments were under way to see just how these waves could be put to work. Two years before Hertz died, William Crookes threw out the hint that these vibrations might be used in wireless telegraphy. Long before this, efforts had been made to send messages across bodies of water or to moving

trains. In each of these attempts the earth or water was used as a conductor in place of the metallic wire. Samuel Morse, of telegraph fame, succeeded in sending his code across a canal at Washington in 1842. He used two metal plates on each side of the canal, one pair of which was connected with batteries, while into the circuit of the other pair a receiver's key was set. The current moved through the water, was picked up by the second pair of plates, and faint signals were distinguished at the key.

This was a crude system and of no practical value. It was identical with the scheme used by a Scotsman named Lindsay, of Dundee, who claimed its invention and patented it in 1854. He used it to send messages across the river Tay.

All of these early attempts at wireless were of the same nature, and their value was slight. It was not until Hertzian waves were put into the hands of inventors that any real advance was made. Here is where Marconi steps in and forever after dominates the story of wireless.

7

Guglielmo Marconi, born in 1874 of an Italian father and an Irish mother, had a natural bent for physical and electrical science. He proved this during his years of private study at Bologna, Florence, and Leghorn. It was during those years that Hertzian waves were discovered, and the keen interest they aroused drew them to Marconi's attention. His young imagination was fired; he was not yet twenty when he became convinced that these waves would make possible wireless telegraphy.

Once that notion got firmly set in his head he never gave it up, and thus wireless became the work of his

life. When only twenty-one he was experimenting at his father's home near Bologna—and getting results. That summer he succeeded in sending signals to a receiver more than a mile away. The next year he was in London, and at twenty-two took out the first patent ever granted based on the use of Hertzian waves.

The next year, back in Italy, Marconi was sending messages across twelve miles of water. Everybody could now see the commercial value of Marconi's invention. A group of far-sighted London business men, in July, 1897, bought Marconi's wireless patent rights in all countries except Italy.

The first commercial use of wireless occurred in the summer of 1898, when Marconi, from a tug in the Irish Sea, sent a report of the Kingstown regatta races to the Dublin Express. Even after this demonstration, the wise and incredulous public still called it a plaything. Boys in funny long-tailed coats and corsetted girls in street-sweeping skirts chattered about wireless and said it was wonderful but what earthly use was it.

The next year, 1899, these chitterings changed. On March 3 the lightship East Goodwin was run down by a passing steamer. Instantly across the water went the cry of distress—a voice out of the invisible calling for help. Lifeboats rushed to the rescue, and men, who would have been doomed to die in another age, were brought safely to shore.

In the year 1901, signals from across the sea, coming from Poldhu, England, flashed into St. John's, Newfoundland. No wires here and no cable. The wise ones had told Marconi a thousand times that the curvature of the earth set a definite limit to the distance at which his signals could be picked up. The waves, they insisted, must travel in straight lines, and so fly off into space while the curving earth fell away below them.

This sounded reasonable to everybody—except Marconi. "These waves of mine will follow the earth," he said. "All we need is power at the vibrator and a sensitive pick-up at the receiver, and we can signal to the antipodes." As usual Marconi was right, and his message to St. John's on December 12, 1901, convinced even the habitual doubters. The next year Marconi sent his signals across two thousand miles of sea at night, but by day they were limited to seven hundred miles.

When he told the Royal Society, in June, 1902, that transmission was better at night than during daylight, the members laughed at him. Marconi, they said, had made a mistake, and the differences he discovered were due to other things. But Marconi had a habit of not making mistakes. Now every schoolboy knows reception is better at midnight than at noon, and the wise ones are again convicted of error.

Thus wireless, through the work of Maxwell, Hertz, and Marconi, came into the world.

8

Lee de Forest, a year older than Marconi, was born at Council Bluffs, Iowa, August 26, 1873. Here also was a man with the gift of practical imagination. He, too, was early attracted to the study of Hertz's waves and dreamed of training them to speak the language of humanity.

Educated at the Sheffield Scientific School of Yale, he received his doctor's degree in 1899, and went at once to the Armour Institute of Technology at Chicago, where he continued his scientific studies. A little later he joined the Western Electric Company and began experiments in wireless telephony. He was the first to use the alternating-current generator and trans-

mitter. These developments were later used on all wireless apparatus. To him belongs the honor of an invention that made the radio a practical, working tool. This is the Audion amplifier.

In the early years of this century it looked as if there was an honest overlapping of rights in the wireless between Marconi and de Forest. So serious did this conflict become that suit was brought by the Marconi Wireless against the De Forest Wireless and a decision was asked by the United States Circuit Court. Judge Townsend's opinion upheld the Marconi interests. So clear did Marconi's priority seem to be that the court made the flat statement:

"Marconi was the first to describe and the first to achieve the transmission of definite and intelligible signals by means of Hertzian waves."

It is interesting to note that Judge Townsend, in this decision of May 4, 1905, makes no mention of Edison's "Etheric Force," but confines his attention exclusively to Maxwell, Crookes, and Hertz. He is perfectly clear in his statement of the credit due Marconi as the following paragraph from his opinion shows:

"The exact contribution of Marconi to the art of spark telegraphy may be stated as follows: Maxwell and Crookes promulgated the theory of electrical oscillations by means of a disruptive discharge; Hertz produced those oscillations and described their characteristics. Marconi discovered the possibility of making these disclosures available by transforming these oscillations into definite signals and, availing himself of the means then at hand, combined the abandoned and laboratory apparatus and by successive experiments reorganized and adapted and developed them into a complete system capable of commercially utilizing his discovery. . . . Marconi, daring to hoist his sail and

explore the unknown current, first disclosed the new highway."

9

Though the radio is distinctly an American institution, the first broadcasting of a regular program took place in England in 1920. This effort, however, was short-lived and was of a purely experimental nature. In the United States radio broadcasting grew overnight. It came into New York from the west, but it rushed upon the country so swiftly that stations seemed to spring up simultaneously all over the land.

In December, 1925, there were 578 stations on the air. As a result congestion made it necessary for the government to step in and restore order. This to a considerable extent has been done, and along with this movement has gone a marked improvement in the nature of the programs sent out. Probably the best programs in the world are now being broadcast in America. Advertisers were quick to sense the value of this new titan, and it is largely through their efforts that high-priced talent is brought to the microphone.

What is its future? Will directional waves come next? Or will television be first? With television and keyed waves will radio compete successfully with the newspaper? Is there a chance that it may force a radical change upon all publications? Will the stage and the pictures bow to radio as a master? Will educational institutions have to meet it as a competitor? What power does it hold for war or peace, for mechanical, automatic flight? Engineers are trying to answer these questions and many others. Any day now may bring the replies, and a new world and a new life will be opened to humanity.

Did Hertz, as his detector sparked before his eyes,

realize that he was releasing a giant? As those sparks, barely visible, flashed there, any sneering skeptic might have asked, "What good is it?" And Hertz might have given Oliver Lodge's famous answer, "What good is a newborn babe?"

Hertz lived his brief life and passed on into the invisible, but this echo of his work still crackles around the globe, sweeps with the speed of light through space and reaches out in foolish attempts to whisper in the ear of Mars. All of this because a mathematician believed in his figures and an impractical scientist said, "If these waves exist I'll find a way to detect them." For this hard, grinding, practical world is swayed by the dreamers and grows great through the toil of the despised idealist.

*Chapter Twenty-seven*

# LANGLEY

THERE are some reasons to believe that all life, including this strange creature afterwards known as *homo sapiens,* originated in the slime of the tide waters. Some way and for some reason not exactly clear, it crawled out of the muck and shook itself on dry land. Certain forms, still unsatisfied, sprouted wings and took to the air. Others climbed trees, spent a few million years swinging by their tails, then dropped down to earth and legged it for the mountains.

"Upward, ever upward," seems to have been the slogan blazoned on humanity's banners. Even before he could write, something framed that catchword for man, burned it into his brain, where it still glows like a bit of radium. Men took to horses, to ships, to gas-raised balloons, to steam-engines, to horseless carriages, to airplanes. At all times and in all places men have envied the birds. That was an instinct, a prodding, driving instinct, and there was no stopping him until this urge was fulfilled. "If you want a thing badly enough—"

Centuries have passed since man first dreamed of flying. Centuries have passed since he first tried to fly in crude ignorance of the weight of his own body. There are tales out of China of men actually flying with some sort of flapping mechanical wings. The records are crammed with accounts of men who dared too much and not wisely. It was of course perfectly

natural that man should at first cling to the idea of making movable wings for himself and operate them by muscular effort. This is the way birds fly, and man foolishly tried to copy their flight. All such efforts ended in disaster.

Not all of the pioneer would-be fliers pinned their faith to flapping wings. A. J. P. Paucton thought that vertically rising propellers or screws would do the trick, and he described such an arrangement, called "pterophores," in 1768. This idea was taken up by Sir George Cayley in 1796, and he succeeded in making a small model consisting of two screws, one above the other and rotated in opposite directions. This would rise in the air. In 1859 an Englishman named Bright took out a patent for a machine to be sustained by vertical screws. A little later a couple of Frenchmen made a machine on the same principle, which would rise, when the propellers were operated by clockwork, to the height of ten or twelve feet.

All of these were mere toys, interesting as hints of man's instinct to fly. But all through that hurried nineteenth century the world was gaining great momentum toward new and marvelous things. So it is not surprising that in 1866, F. H. Wenham designed and built a machine with planes, one above another, and this machine he called an aeroplane. As much through lack of a proper engine as anything else Wenham never succeeded in getting anywhere with this first airplane.

In 1874 Thomas Moy attempted to solve the problem with a very ambitious machine. He also used planes, long and narrow, but added two enormous propellers and a light steam-engine. The machine rested on three wheels, and the idea was to drive it across a level stretch and when the speed became great enough it was expected to dart into the air. Everything was

fine except the fact that the miserable contraption wouldn't rise.

2

Is there an accumulation of race wisdom that gets into the very germ cells, so that every now and then a man is born with an enlarged instinct for some problem upon which mankind has labored for ages? Would a notion of this kind account for Newton and gravity, Pasteur and microbes, Mendel and heredity, Langley and flying?

Samuel Pierpont Langley was born at Roxbury, Mass., August 22, 1834. As a boy he was more than normally interested in the way birds use their wings. All boys, enviously, watch birds fly and speculate idly as to how they do it. At least, that was true forty years ago. Today there isn't much left for them to dream about. But Samuel's speculations were not idle; they were direct and analytical, backed by keen observation.

Some way he got through the Boston High School, but college was out of the question. Sam's main business at that time was to earn a living, and as a high school graduate he probably thought himself pretty well equipped to grapple with life on even terms. The amazing thing is that he coolly decided to be an engineer and architect.

He didn't expect either fame or fortune, but he thought "a chap who was fond of mathematics and drawing should be able to do some good work in the way of building." Spurred by this not extravagant ambition, he went to Chicago, a bustling little city in Illinois. This was fifteen years before the great fire, but the town was growing by leaps and bounds, and anything in the shape of a building engineer who could draw plans and throw a structure together was in de-

mand. Langley prospered, and his thrifty nature led him to save his profits, so that at the end of seven years, when he was thirty, he found it possible to give up his trade and go back to science.

During the next three years he built telescopes and studied astronomy. After a year in Europe, Winlock offered him a place as assistant in the Harvard observatory. Langley was thirty-six when he left Harvard and went to Annapolis Naval Academy as professor of mathematics and director of the observatory. There was no college degree back of this man; he had spent no time with dry-as-dust tomes, but he had used his eyes and his head and his divine right to ask questions and remember the answers.

Grown to such proportions that little Annapolis couldn't keep him, Langley stood out as the most desirable man when the Western University of Pittsburgh began to look around for a professor of astronomy and physics. So to Pittsburgh he went, and it was there that the best of his work was done. There he struggled with the invisible rays of the spectrum and invented, to help him in analyzing the infra-red rays, his bolometer, an instrument so delicate that it will detect a change of temperature amounting to less than one-hundred millionth of a degree. It was with this that he demonstrated the existence of the totally unsuspected "new spectrum," where he found rays with wave length greatly exceeding anything before known.

### 3

All of this doesn't seem to have much to do with the flight of heavier-than-air machines. But one needs to realize that Langley was first of all a scientist, an experimenter, and a cautious, sound workman. When he returned to his boyhood question of "How do birds

fly?" he tried first to find the answer in his laboratory. There were a hundred problems wrapped up in this one, and his plan was to separate them, study them, evolve the basic laws.

In his laboratory at Allegheny he had a whirling table set up, the arm of which could be revolved at any speed up to seventy miles an hour. Here he made minute calculations as to the buoyancy of air. He found that the old books were wrong, as he had suspected, because he said if they had been right, "a swallow would need the strength of a man to keep itself in the air." After a long series of experiments with his table he was sure he knew at last the exact relation between speed, wing expanse, and air buoyancy.

About this time he was called to Washington as secretary of the Smithsonian Institution. But he did not let his new work interfere with his studies of flight. He thought the time now had come to demonstrate with a model machine the accuracy of his conclusions. The engine for this model gave him more trouble than all the rest of it put together. He tried steam, carbonic acid gas, and compressed air; steam was the only one that worked satisfactorily. But these experiments took time, and it was not until May, 1896, that he was ready for a real trial.

His machine weighed thirty pounds, was sixteen feet long and about thirteen feet across the wings, and carried a quart of fuel. As he didn't want the model to be smashed when it came down he planned to fly it over the Potomac River. On the sixth of May the machine was tested, and it flew. There were two trial flights, each of which lasted about a minute and a half and in each of which the plane flew about half a mile. It remained in the air until the fuel was exhausted and then settled down gently on the water.

Man had conquered the air.

Of course, this trial machine didn't carry a man; but obviously if one were big enough it would swing a man up into the air and give him supremacy with the birds. That's what Langley thought, and that's what the government at Washington thought, and congress voted him fifty thousand dollars to be used in building a man-carrying airplane.

4

Man rises by setting his feet upon the bones of those who have failed. More than once it has risen over the crushed forms of those who were in advance of their time: such as Roger Bacon, Bruno, Langley. If Langley had only had a Victory engine—any workable and dependable gas engine!

Full of courage and confidence he set about the building of his flying machine. In every respect it was to be like his successful model, only larger, and because of engine and fuel capable of a more sustained flight. For seven years he worked over this machine, testing it, experimenting, hoping. In 1903 he was ready to prove himself.

Out on the banks of the Potomac the machine was housed. Would it fly? Why not? Models exactly like it had flown for half a mile, for three-quarters of a mile. An elaborate launching device had been designed by Langley and was ready to be put into use. For some reason, lost now forever, Langley had not chosen to launch his machine by driving it on wheels over a level track until a lifting speed was attained. He knew of such devices, but he preferred to shoot his plane straight into the air.

The eyes of all the world were centered on Langley. When would he fly his machine? No one knew, and,

in order not to be caught napping, reporters from all of America's great daily papers actually camped out near the shed in which the machine rested. Langley wanted seclusion, wanted secrecy, wanted to make his test at his leisure. But there was no privacy for him and his enterprise.

At last it was apparent to him that the test could be no longer delayed. A crowd of witnesses was on hand when the effort to fly was made. As the plane surged into the air something went wrong with the launching device; the machine was not properly released, and it dropped at once into the water.

There were cackles of derision, and the next morning the country read of Langley's failure. But Langley was not discouraged. He felt sure the fault was not in the plane and he at once set about arranging for another test. This time no detail was overlooked, and every possible precaution was taken to see that the machine was given a chance to get into the air.

Fate, however, was against Langley; a rope catching in the tail-piece dragged the machine, nose first, into the water. The engineer was, with difficulty saved from death, and the machine was torn in pieces in getting it back to land. Langley had failed.

The next morning every paper in the United States burst into hysterical laughter at "Langley's Folly." Ministers preached against the effort as an affront to God. "If God had meant men to fly He would have given them wings," they shouted. Grave and learned scientists said that gravitation could not be overcome and that birds flew because they had hollow bones and their feathers were light! This is no exaggeration; these things were actually said only a quarter of a century ago.

Langley's appropriation of fifty thousand dollars

was exhausted, and a farmer-congress with the words "Langley's Folly" ringing in its ears refused to vote him any more money. Langley's heart was broken. He knew his machine was right; he knew it had not been tested and that the fault lay in the launching device. He begged for one more chance, but there were to be no more chances for him. In 1906, crushed by the derision and criticism of a blind people, he died. But his models had flown, and the world was never again to be without its heavier-than-air machines.

5

Fortunately before Langley died, he had passed much of his wisdom on to Wilbur and Orville Wright. Like him, these brothers approached their problem warily. For long they studied the flight of birds; for many months they confined their work to gliders, secretly working out the principle of their machine far from prying eyes.

In the very year, 1903, that Langley's Folly failed to get into the air, the Wrights were flying for fifty-nine seconds. Two years later they made forty-five flights and remained in the air for half an hour, flying twenty-four miles.

At just this time automobiles were coming into use. This meant better and more dependable internal-combustion engines. The Wrights were on hand to take advantage of these new engines and to find them serviceable in airplanes.

In 1908 at Fort Myer, Virginia, in a government test, Orville Wright flew his plane one hour and three minutes. Later he took a passenger with him and flew four miles in six minutes.

As I write a plane flashes into my field of vision, dips and circles gracefully as a great bird and roars

away toward the horizon. During the little more than twenty years since Orville Wright flew at Fort Myer, regular air-mail service has been established in Europe and America; passenger service is regular in Europe and has begun in this country; the ocean has been crossed; San Francisco has been brought within twenty-four hours of New York, and planes have circled the globe.

But the genius of man, firm in its confidence in a soaring plane, is making every effort to solve the last great problem. Vertical ascent and vertical descent have yet to be achieved. This may come at any minute; it may be part of the regular equipment of every machine even before this book gets into your hands. At any rate, it is just around the corner, and, with its coming, planes will dot the skies as cars now cover the roads.

For ten years Langley's Folly rested in the National Museum at Washington. At first visitors went to laugh at it; later they went to wonder and question, "Would it have flown? Did it ever really have a chance?"

Glenn H. Curtis decided that these questions deserved answers, and he applied to the government for permission to fly Langley's Folly. He installed a modern engine, but it is claimed that otherwise he made no changes in the machine that had twice crashed into the Potomac. In May, 1914, the test was made, and the machine proved itself capable of sustained flight.

Langley's Folly then turned out to be wisdom in advance of its age. And where now are the jests and the howls of derision and the preachments concerning God and His intentions? Lost in that limbo west of the moon.

*Chapter Twenty-eight*

## EINSTEIN

ALBERT EINSTEIN was born at Ulm, Wurttemberg, May 14, 1879. His father was a dealer in chemicals, and there was an atmosphere of science around Albert from his earliest childhood. His father opened a business at Munich soon after his son's birth, and even today, over sixty and world famous, Einstein has no love for that city. It was there he first went to school and it was there he first learned the bitterness of being a Jew in Germany. He was too small and lonely to fight and too sensitive to ignore the cruel gibes. But oblivion has swallowed up the Munich boys who abused little Albert.

When he was fifteen, Einstein's father took his electro-chemical business into Italy, and Albert escaped into the somewhat freer air of Aarau, Switzerland. Of his life at the cantonal school there, he makes no complaint but it is significant that though Pasteur, Darwin, Wallace, Hooker, Gray, all had close friends, Einstein, like Lamarck, has lived a lonely and isolated life, his sweeping imagination building for him a world in which he rules supreme as the only human being there.

2

Einstein's genius must have budded early, for when he left Aarau he was ready to earn his own living. At Zurich he entered the polytechnic school, paying his

way by teaching mathematics and physics. Like Pasteur he wanted only to be a teacher. With that idea in mind, he went to Schaffhauser and for a year served as a tutor.

It is doubtful if his work as a private teacher was wholly successful, because the next year he became a Swiss citizen and was glad to get a job as examiner of patents at Bern. Bobby Burns, as exciseman, presents no stranger figure than does Einstein, toiling dutifully in a patent office, laboriously checking designs and models in an effort to prevent infringement.

Naturally this was only bread-and-cheese work; it could not stop the whirling of Einstein's brain, and in his odd moments he attended the University of Zurich and won his Ph.D. Also during this patent period he found a girl of Slavic parentage who was interested in mathematics and in one mathematician—and her he married. Probably this girl of Slavic parentage accepted Albert because she saw that he needed someone to look out for him. At any rate, they failed to establish a permanent common ground and, apparently with mutual satisfaction, the marriage was dissolved.

3

Seldom did a man make such good use of a government job. Einstein not only got himself a wife and a doctor's degree, but he also wrote and published papers that established him as a scientist of learning and imagination. In one of these early papers, which attracted wide attention, he gave an explanation of the Brownian motion. This phenomenon, discovered by Robert Brown in 1827, had ever since been a puzzle to scientists.

Briefly, what Brown saw through his microscope was this: minute particles suspended in a liquid were

seen to be in a state of great agitation. But why these bits of matter, just large enough to be visible under a powerful glass, should so busy themselves darting here and there was a dark secret. This was the problem Einstein attacked while he was still busy checking up on patents.

His theory was that heat increases molecular activity. But this activity cannot be seen in a large particle nor can it be seen in a molecule, which is too small to be reached by any microscope yet made. However, this heat motion can be seen, Einstein contended, when the particle is just at the limit of man's microscopic vision. But he wasn't satisfied to rest on this theory: he went ahead and used his mathematics to prove he was right, giving equations which made it possible to deduce the masses from the motion of the particles.

He was still scrutinizing patents when, in 1905, he put out his "Special Theory of Relativity," a deduction growing out of his study of the Fitzroy-Lorentz Transformations—an equation so subtle that its full significance was not realized until Einstein illuminated it with his genius. The masters of science began to look attentively at this worker in a patent office. Zurich said, "Come and be extraordinary professor of theoretical physics at our University." This was in 1909, and Einstein stayed there for two years, when Prague beckoned him as professor of physics. But Zurich took him back from Prague after a year, and he was still there as full professor of physics when Germany demanded him.

## 4

Einstein was called to Berlin as director of the Kaiser-Wilhelm Institute, made a member of the Royal Prussian Academy of Science and given an in-

come large enough to enable him to devote all of his time to research.

Two years later he astonished the world with his "General Theory of Relativity."

At that time, 1915, Europe was trying desperately to commit suicide and drag all humanity into the grave along with her. Berlin was a seething center of war activity, but like Lamarck, whose calm was undisturbed by the fury of the French Revolution, Einstein locked himself in his laboratory and escaped the virus of madness that afflicted whole nations. When this poison wore itself out and men became rational again, the startling nature of Einstein's idea of the universe stirred savants to a fierce probing of its truth.

In effect Einstein said that space was curved and that particles moving through space would follow the curvature of the continuum. But was there any proof of the truth of this statement, which on the face of it sounds like pure nonsense? Einstein could immediately point to one supporting fact:

For a long time the believers in Newton's law of gravity had been annoyed with Mercury. The planet wouldn't behave itself and finish its journey around the sun decently, ending at exactly the point where it began. Instead of this Mercury had to go a little more than once around the sun to make a complete trip. Newton's theory wouldn't account for this weird behavior; Einstein's theory did account for it, almost exactly.

Then there was the matter of the lines in which light moves. The old idea was that light, not being composed of material particles, ought to move in straight lines in a vacuum, regardless of gravity. However, Newtonian theorists admitted that when a light ray passed near the sun it might be deflected from a straight path as

though it were composed of material particles. Einstein, however, calmly insisted that, according to his law, light would be deflected twice as much as Newton's law called for. It was this contention that particularly agitated physicists and astronomers.

Fortunately it was one of those things that could be tested, and an opportunity to test it soon arrived.

5

The war ended. Germany, shorn of her greatness, was begging at the World's Court for a new chance. On May 29, 1919, her judges gathered in Paris to pass sentence upon her. And at that very moment wise men from England were in Africa and Brazil equipped to photograph an eclipse of the sun and determine once for all whether Albert Einstein knew what he was talking about.

The results showed that he did.

The pictures proved that light, passing near the sun, is deflected from a straight path to almost exactly the degree Einstein had predicted. Photographs made during the eclipse of 1922 furnished further substantiation.

While the world of science was waiting impatiently for the astronomer's verdict, Einstein remained at home in Berlin and with pipe in mouth went quietly about his business, laboring over equations, struggling into a world of hard, cold reality where there is no sentiment and no emotion. If he had solved his equations correctly, if he had made no error in juggling his figures, he knew his deduction must be right. If the observations did not justify his conclusions, then the work would have to be done over again and with great care the error probably could be detected. There was no reason, then, for being worried or disturbed.

When the word came through that his theory had been proved correct probably he felt a mild glow of satisfaction; but with these mathematicians one can't be sure even of that. Certainly there was nothing in his conduct to justify the charge that Einstein is vain. On the contrary, those who know him best speak often of his modesty and insist that the word "I" gets into his conversation very seldom. At the time of his first visit to America he appeared as a quiet, unaffected, sincere little man much in love with his pipe, possessed of a fine sense of humor and an honest horror of formality in human relations.

6

Nor is there any pretense or assumption of greatness about him. In this he is like Faraday, the simplicity of whose life was unchanged by fame. He has none of the climbing instincts of Davy and none of the theatrical attitude that was so strongly marked in Pasteur.

His home on Haberland Street, Berlin, was as unpretentious as a flat in the Ghetto. He and Frau Einstein, the second, once his cousin Elsie, lived on the fourth floor of an apartment building, and to the other tenants he was just a middle-aged sick man who kept very much to himself. On the fifth floor, directly under the roof, was Einstein's workroom. Not a large room, but large enough for a man to think in. A steel door shut him away from noise and intruders; a skylight let in air and sun and gave a view of the stars at night. In this room, with the door securely closed, Einstein was in another world, a world of more than three dimensions, where there is nothing but silence and profound thought.

His desk was littered with scientific journals, letters, books and scratch paper carrying equations in varying

stages of solution. And over all were tobacco and ashes, for an absent-minded man who is an inveterate smoker is bound to be careless in filling his pipe and likely to drop the burned ends of matches almost anywhere. On a chair near his desk stood an unframed sketch of himself done by an unknown artist.

In one corner of the room was a long brass telescope, and in the still hours of the night Einstein pointed it toward the stars and peered anxiously out, eternally asking questions of the distant twinkling suns.

All of these things one would expect to find in the room of the world's greatest scientist, but would one expect to find, opposite the desk of such a man, a grand piano? Yet there it stood, symbolizing a side of Einstein's nature not familiar to the world. He loves music and when the forces of thought grow overwhelming and threaten his destruction, he goes to the piano and out of the music of Beethoven and Bach reestablishes his inner harmony. Darwin, who in his youth so loved music that his backbone crept when he was listening to an orchestra, complained that his work in science had destroyed his appreciation of art. Einstein, who seems to have followed abstractions beyond the limits of human thought, still finds in music an uplift and a solace.

Honors and fame and some money have come to him, but he lives in Princeton, N. J. today in the same atmosphere of modesty and scholarship as then.

7

It was from this room that Einstein announced his General Theory of Relativity—which shook the scientific world. In this new idea, supported by mathematics and backed by experiment, "space in itself," says Minkowski, "and time itself sink to mere shadows, and

only a kind of union of the two retains an independent existence." Is it any wonder, then, that Science sat up with a jerk and said, "What's all this about?"

So feverish was Science's question that even the layman became interested. Was the universe changing under his feet? Was the watch in his pocket lying to him? Was time an illusion and space meaningless? Naturally, as laymen, we asked a lot of questions, some of which were silly and some of which called for answers that could be grasped only by an enlarged mathematical understanding. We wanted to know what all the shooting was about—and no one could tell us.

We had all heard of the fourth dimension—and dismissed it as the idle dream of a cracked mathematician. Then suddenly all the world was talking of a fourth dimension called time—and we went around with a vacant look in our eyes and a numb spot in the middle of our head. We were trying to visualize space-time—and that way madness lay.

Recently Einstein has given his "Field Theory," and we are again groping. This thing called gravitational field and this called an electro-magnetic field are identical, says Einstein, and one law governs them both. A. S. Eddington, professor of astronomy at Cambridge, complicates matters by taking a rap at the electron. We had got rather used to this smallest of the small and had begun to feel neighborly toward it; then Eddington came out and said it's only a "dummy" used to help thought and that underneath it is psi, which is supposed to be the reality but may in its turn prove to be just dummy stuff.

Between them Einstein and Eddington have pretty thoroughly wrecked the old order of things, that order to which we were born and about the laws of which we imagined we knew something. Fortunately for us,

the laws still work, but it doesn't follow that they work as we thought they did. That doesn't matter much, but it's a bit of a shock to us believers in Newton, who has straddled the world like a colossus for more than two hundred years.

If Eddington is right and the electron has to go, can we have any confidence in the stability of the psi? And if that also goes, where are we left? Are we nothing, or less? Is all matter nothing, or less? Einstein has taken away time as a fixture and space as a reality and the yard-stick as an undeviating measure of length. It's all very confusing, but time, to the reality of which we stubbornly cling, may tend to clarify things and give us a glimpse of where we're headed.

8

Newton's theory was a deep mystery to the men of his age. There were only a half a dozen men living who were able to see exactly what he meant. To some extent his ideas were sensationalized for the purpose of helping the non-mathematical mind, if there is such a thing, get a picture of the world swinging swiftly through space and yet all the time held undeviatingly in the strong grasp of the sun. During the two hundred and fifty years that have passed since "Principia" was published, human beings have, in some wholly bewildering way, accepted and assumed that they understood Newton's theory.

The non-mathematical mind gets a vague, but satisfactory picture of gravity by visualizing a ball flying around at the end of a string. This is far from accurate, but it has served and continues to serve the harassed business man and the active housewife. It is not impossible that many people still harbor the secret belief that Newton's idea is silly and that there must be some-

thing tangible and visible which in some way supports the world pretty much as a ball might be balanced on the end of a pole. This is a perfectly natural line of thought if one has not received a mathematical training.

Most people, and this includes the genius of Shakespeare, Goethe, Hardy, and Proust, are able to think only in pictures, in clear or illusive mental images. Only the enlightened student of pure mathematics is able to escape this limited and unsatisfactory process of thought. As such a one follows the steps of the Lorentz Transformations he gets no picture expressible in terms of every-day prosaic existence. In this work he is carried into a realm where even words, in their ordinary image-creating sense, cease to exist, and where thought is so hard and cold and remote from humanity's daily experiences that, to the non-mathematical, it can no longer be identified as thought.

If you watch yourself you will find that you think only in words which have for you definite pictorial value. It does not follow that your words will have the same pictorial value for anyone else in the world. If you are a broker on Wall Street the word "cotton" will mean something different to you from what it will mean to the owner of a cotton plantation in the South, and again it will mean something entirely different to the negro who gathers the pods. But in each instance the word will have direct and expressible pictorial value.

This haphazard meaning of words does not exist in the higher mathematics. To the few profound students who are capable of following, say, a Riemann formula, the significance of the formula will be the same; literally, the processes of thought will be identical.

How then can these unpictorial conclusions be expressed in words that must carry, and cannot avoid carrying, pictorial suggestions?

9

Einstein is a colossus of pure mathematics. When he enters his laboratory he shuts out, with his steel door, all words—as we understand words. He deals with formulæ, with combinations of figures, letters, and diagrams, in the manipulation of which the ordinary vocabulary of the world has no part. When the time comes to give his conclusions to the world he prints a few pages of formulæ—and immediately volumes are written in an effort to give a picture of something that cannot be pictured.

Einstein has not much meaning for the layman, in spite of all the books, pamphlets, articles, lectures and interviews about relativity. A popular account of Eddington's electron theory was written for the London Times, and Sir Oliver Lodge was asked to comment upon it. All he had to say, after reading it, was, "God help the readers of the Times!"

Bertrand Russell, who as a student of pure mathematics stands second only to Einstein himself, says, "Many of the new ideas can be expressed in non-mathematical language." But he hastens to add that in order to understand them a change "is demanded in our imaginative picture of the world."

Can you change your picture of the world? Can you wipe out of your mind the idea that the sun "holds" the earth and the other planets to their orbits? Can you put in place of that a picture of the planets loafing along, following, in a sense, the line of least resistance—not because of anything the sun does to them but because of the nature of space-time? Can you think space-

time? Can you get a picture of it? Does this combination of words mean anything to you?

It means something to the mathematical student of Einstein. For instance: When you see a book, it's just a book to you; something heavy, and solid; it can be handled and seen and read. You can tear it or twist it or burn it or throw it in the garbage can. You realize, instinctively, that if it occupied no space, it would have, for you, no existence; it would be at best only the ghost of a book through which you could stick your fist.

Now the idea of associating time with that book never enters your head although you know of course that unless it exists for some time, however short that time may be, it has no existence. The camera can take motion pictures, because no matter how fast a man is running there is always a fleeting fraction of a second when his legs are still. So you see you must add time to your book in order to give it a reality upon which you can lay your hand. If you shorten your time to zero it is the same as saying that the book does not exist. You must use time as a fourth dimension, or your book has no reality.

## 10

Now to Einstein and some others, the book is not a bit of solid matter occupying space and time, as it is to you and me, but it is an Event, a group of neighboring events. Here at once we get into trouble, because the word "event" means something different to us from what it means to a mathematician. The blowing-up of the Maine was an event to us, but we would never dream of thinking that the book we hold in our hands is an event. If it is a great book we might think of its publication as an event, and mark time from it.

In other words, we, like the scientist, fasten time to our event; but the difference lies in the fact that he calls everything an event and for this reason: Space-time is a necessary dimension of everything that we naturally think of as matter. Moreover, he will not speak of the distance between two events nor of the time between two events as we should, but of the "interval" between them. And the measure of his interval in the special theory of relativity is the distance light would travel in the time between events.

The velocity of light tends to dominate the whole theory of relativity. We can know nothing that can beat the speed of 186,000 miles a second. You can think of this speed as the standard. Some strange things happen as a natural consequence of this phenomenon. Once you get this matter clearly in mind, you will be in a fair way to understand as much of Einstein as can be told without mathematics.

II

If you are driving twenty miles an hour and a car traveling forty miles an hour overtakes you, at the end of an hour if you both maintain that speed, the two cars will be twenty miles apart. If you are driving twenty miles an hour and meet a car going in the opposite direction at forty miles an hour, at the end of an hour you will be sixty miles away from the car you met. These examples are childish, and everybody understands them perfectly, but does everyone understand this problem:

You are traveling at the rate of twenty miles an hour and you meet a car traveling at the rate of forty miles an hour going in the opposite direction. Now suppose at the instant the cars pass each other, a flash of light is sent out from your car. How far will you be from

that wave of light at the end of a second and how far will the second car be from the same light wave at the end of a second? The answer is that each car will be exactly 186,000 miles from the light wave. Exactly, mind you. That is to say, neither your speed nor the faster speed of the second car will change the result in the smallest fraction.

This sounds impossible? Not at all. The fact is that you, the driver of the second car and everyone else who was in that immediate neighborhood at that instant each became the center of the flash of light; and, if each driver held in his hand a perfectly adjusted watch, each would find at the end of a second, that the light ray, if there were any way of measuring it, was 186,000 miles away, just as it would have been had each of you been standing still.

There is only one way of explaining this paradox and that is upon the assumption that your watch and the watch of everyone else has been affected by motion. This doesn't mean that there has been a mechanical change or inaccuracy in your watch; it means that there has been an actual change in the length of the second. This effect of motion on time leads to some queer results.

We said that in dealing with the Einstein theory we could think of velocity of light as absolute. And so we can, because no material body can ever under any circumstances quite attain the velocity of light. This is obviously true if time is affected by velocity. If your time changes as your velocity increases, while the speed of light remains constant, how can you ever reach that constant?

This is closely analogous to the difficulty you run into if you start to walk from New York to Philadelphia, with the understanding that each day you are to

go half of the distance that separates you from your destination. You would go forty-five miles the first day, twenty-two and one-half miles the second day, eleven and one-quarter miles the third day, and so on. But never would you be able to drag yourself across the last indescribably minute fraction of distance that separated you from Philadelphia. So if your time changes steadily with your increase in velocity, how can you hope to reach a standard that is fixed and absolute?

12

It is this change in time that introduces so many apparently fantastic things into this theory of relativity. For instance, there is the well-used example of the twins. Suppose they set out on a twenty years' journey through space, traveling separately but at uniform relative speed. When they meet at the end of twenty years, each will think the other younger than himself. And why not, since the velocity of each has shortened the time for the other? Though neither would be conscious of any change in time in the particular apparatus in which he was traveling.

Suppose again that while these twins are traveling, a star explodes, and the explosion is visible to each. Will they agree as to the date of that explosion? How can they since their watches are, relatively, out of kilter with each other? And if a third person who was at rest with reference to the traveling twins saw the explosion, would his date agree with either of the others? Obviously not.

Is all of this a little grotesque and obscure? Remember that Bertrand Russell said that a "change is demanded in our imaginative picture of the world." Can you make that change in your picture of time? The trouble lies in the fact that for ages humanity has

looked upon time as definite and changeless. Yet Einstein shows that it was never anything of the sort.

By the merest accident of mathematics we have a day that is twenty-four hours long. Quite arbitrarily we have cut those hours up into minutes and seconds. As a result, you see, humanity's clock is the earth, plus a check-up provided by the rest of the solar system. Now suppose that throughout our visible universe the rate of movement changed uniformly, and the speed of the earth changed along with it. What effect would this have on time? As far as we are concerned the earth would still revolve in twenty-four hours, would it not? But each hour might be twice as long as it is now, or half as long. But each minute and each second would change along with it, and how should we ever become conscious that the motions in the universe had speeded up or slowed down?

If our solar clocks maintain uniform relative speeds, no change in their velocity could ever be discoverable by man. Will this help us to see that what we call time, by which we govern our movements on this little world, is arbitrary, elastic, and surprisingly uncertain? It may then be easier to imagine a universe in which time is dependent upon velocity, and realize how, in that universe, each of these twins may be younger than the other. It may also help us to understand why it was when three observers saw a star explode, no two of them agreed as to the time of the explosion.

13

Relativity, as an idea in physics, is certainly as old as Galileo and is therefore not original with Einstein. In fact, it may surprise you to know that this man around whose name the term relativity is so universally woven has really been trying to do away with rela-

tivity. In this sense, at least—that he has tried to find the simplest basic laws upon which physics could rest. He has searched for terms of measurement that would give the same result regardless of the position of the observer, "so that the phenomena of nature will be the same to two observers who move with any velocity whatever relative to one another."

The idea of relativity in motion is, as we said, as old as Galileo. If a ball is tossed up in a moving train it will fall vertically to the floor. Yet an observer, standing on a platform outside the train and watching that ball will say that it falls in a curve. If you are walking through a moving train on your way to the dining-car, you know that you are in motion with reference to the train. Also, when you remember it, you know that the train is in motion with reference to the earth, otherwise you'd never get anywhere.

But do you at the same time remember that the earth is in motion with reference to the sun? And that the sun is in motion with reference to what we call fixed stars? And that Hercules, toward which the sun is flying, may be in motion with reference to some more distant star? Do you then see the highly involved curve through which everything, because of these many motions, is moving? If you do you will understand what was meant by the old physicists when they spoke of relativity.

It is apparent that this restless universe, which is never for two seconds at a time the same, could not be measured unless time were somehow made a part of the scheme of measurement. When Newton said that between any two particles there is a force which is proportional to the product of their masses and inversely proportional to the square of their distance, he meant *at any given moment.* But, as we have seen, the

"given moment" as well as the distance will depend upon the position of the observer. It was to escape this ambiguity that Einstein introduced space-time. In this way he does not measure the distance between two particles but rather the "interval" between two events.

In this general theory of Einstein's, only neighboring events have a definite interval. Hence the interval between distant events has to be arrived at by dividing the route into small bits and then adding up the intervals for these various neighboring bits.

You know that the shortest distance between two points on a globe, say the earth, is not a straight line, but is along the path of a great circle, like the equator or any one of the meridians. If you are going east from New York, and want the shortest route, you will swing north, following the line of an imaginary great circle or geodesic. This is the most direct way and is the route Lindbergh followed in his flight to Europe.

Solar bodies in their movements do exactly the same thing: They follow geodesics of space-time. Under Newton's theory every body tends to move in a straight line unless acted upon by an outside force. But to Einstein there are no straight lines, no body can have a tendency to move in a straight line. His conclusion is that the orbits of the planets are geodesics in space-time and that the planets move in them because of the curved nature of space-time and not at all because of any mysterious force that the sun exerts over them—a force which must of necessity work at a distance—an assumption which is repugnant to our way of thinking.

14

So little does Einstein believe in straight lines that he will not even admit that rays of light move in straight lines. On the contrary, he assigns to the light

rays geodesics and assumes that, unless they are stopped by some opaque body, they will travel around the entire universe and return to the point at which their source was when they began their journey. This entire jaunt for a light ray would occupy the mere trifle of one thousand million years. Of course, by the time the rays got back, the sun would have gone far along on its endless trip toward Hercules.

You can see at a glance, that if the light waves travel in curves, space as we know it cannot be infinite. That doesn't bother Einstein for an instant, as he agrees at once that space is finite, a something or a nothing that is a thousand million light years in circumference. There may be other space beyond ours, but if so he assumes that our light, not just the light of the sun but all the stellar light rays, can never escape from the universe in which they have their origin.

This space in which these light rays travel is, to Einstein, just space. That is, he doesn't find that his theory calls for an ether, but neither does it necessarily knock out the ether idea. Apparently his assumption is that, if there is an ether, things work exactly as they would if there were none. He hinges a good deal of weight upon the Michelson-Morley experiments, and those made by their followers, which failed absolutely to get any trace of an ether drift; that is, an ether wind. Up to the present, no experiment has shown, conclusively, that there is an ether. Dayton C. Miller, in 1925, thought he detected something or other that might pass as an ether, but neither Eddington nor Bertrand Russell has accepted Miller's work as final.

Originally this ether stuff got into the scheme of things because it was thought the light waves must have something in which to travel. The electro-magnetic nature of light and the zero interval between

particles of the same ray tend to throw the ether into the discard, though so great a physicist as Sir Oliver Lodge clung firmly to it as a beautiful and desirable theory. Whether or not it exists is, at present, a matter of small concern, since in any event it has no effect on the movement of light, and as far as we know it is absolutely transparent. So you can have an ether or not as you please without changing the results.

15

Avowedly Einstein's whole purpose in working out his theory was to simplify and clarify the laws of Nature. Would you say he has succeeded? The mathematicians say he has—and we'll have to take their word for it. Naturally you say, "Why must I take their word? To me the whole thing is as clear as mud."

Higher mathematics is a little like a great piece of music. If you are so unfortunate as to have a bad ear, or even if you are not a trained musician, the chances are that the music will be no more than a pleasant sound, or maybe just a noise to you. An expert tries to tell you what the music means—and fails to make you see it, though you may easily understand Darwin's "shiver of the backbone." The failure is due to the fact that the mental and physical response to music cannot be put into words.

Or better still, say that you, who are not a musician, are looking at a symphonic score, and a great director is trying to make you *hear* what the tailed dots mean. What mental picture can he give you that will be of much help? For the real meaning of music, you have to depend upon those who understand it, feel it, *hear* it.

The mathematically deaf are in the same fix when they talk to one who juggles involved formulæ.

Einstein's theory makes certain assumptions that you

can memorize and then waste your time trying to visualize:

(1) Time and distance are relative and depend upon motion.
(2) Space-time is constant and therefore essential to all accurate calculations.
(3) Space-time is finite and curved.
(4) Light rays travel in geodesics or universal great circles and in a thousand million years may return to the point of origin.
(5) The planets travel in geodesics around the sun because of the curved nature of space-time, and their orbits are the lines of least resistance. The radius of this curvature is dependent on the masses of the solar bodies.
(6) The sun exerts no direct force on the planets, but they travel as they do because of the hills and valleys that lie in their course.
(7) The mass of a body increases with its velocity, and no material body can ever attain the velocity of light—for if it did its mass would become infinite. This increase has been proven experimentally in full agreement with the theory.

Have you absorbed each of these? If you've got them in your head and understand each of them thoroughly, you have the bulk of Einstein's theory.

16

Will this revolutionize the world? Will it change mankind's way of living as Faraday's work did? Or as Pasteur, Lister, Hertz, Roentgen, Langley, and the Wrights did? Will it change philosophy and religion as Darwin did? No one can say what its future will be, but it is safe to say that in philosophy it already has

caused the greatest revolution in the history of human thought.

The time sent out by wire and radio every day is, as far as we are concerned, absolute. The old yardstick and the pound weight work exactly as they did before Einstein was born. You can't use space-time to coerce your debtors or evade your creditors. Geodesics won't enter into your life unless you're a long-distance flier or the captain of a transoceanic steamer; and when you buy coal the measure of the ton won't depend upon the speed with which the truck is driven.

As yet, practically, to ninety-nine and one-half per cent of people, the theory is useless. But if you are an astronomer or a physicist it is vitally important. It is not advanced as the ultimate explanation of the universe. That explanation, final and blindingly illuminating, may come from the tiny, whirling electron, from the proton—from the sub-microscopic solar system, the atom. And in this tiny world of the atom all work depends upon, and is made possible by, Einstein's bewildering theory of relativity.

To one of those stars separated from us by the distance light would travel in a thousand busy years, no human being can ever hope to go. Science can photograph them and analyze and speculate. To say that their temperature is 6,000 degrees, like our sun, or 40,000,000 degrees, as it is said to be in the interior of the distant stars, means nothing. No imagination can get itself into a sweat thinking of 40,000,000 degrees of heat. Fancy shrivels to a crisp a long way this side of such a furnace.

Science, at present, can play with the stars; but the atom is man's real work, and some day it may be brought out into the light and its fierce, strangely

guarded secret laid bare. That will bring a real revolution—if man is lucky. If not, the release of this stupendous secret may blast humanity out of existence, may blast the world into its elements; and a thousand million years may pass before there is a new world and a new heaven and a new curious-minded creature gazing through matted hair at points of light set in the velvet blackness of the night. . . .

THE END

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